FIELD CROPS

AGRICULTURE

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THE

FIRST PRINCIPLES

OF

AGRICULTURE

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Authorized by the Honorable the Minister of Education for use in the Public Schools
of Ontario.

PREFACE.

—

Agriculture is a very broad subject. It embraces so much in itself, and is so closely allied to Geology, Botany, Chemistry, Physiology, and other branches of natural science, that it is very difficult to state even its first principles concisely, and at the same time so clearly and simply that they can be readily understood by children in the third and fourth classes of a public school. Notwithstanding this difficulty, it is hoped that this little work may be found fairly well suited for use in the Public Schools of this Province.

Mr. Mills is responsible for the introductory chapter on "Definitions and Explanations," and for those chapters entitled "The Plant," "The Soil," "Diseases of Crops," "Insects," and "Dairying." Mr. Shaw is responsible for the remaining chapters of the book.

It is proper to remark, that at the request of the Honorable the Minister of Education, advance sheets of the book have been submitted to a number of prominent agriculturists and stock-breeders, with requests for criticisms or suggestions of improvement. It is gratifying to the authors to be able to state that their work has received what is substantially the unanimous approval of those to whom it has been submitted.

CONTENTS.

First Principles of Agriculture.

Definitions and Explanations.

1. Different kinds of Bodies.— As we look about us in the world, we see many different kinds of substances, or bodies, as we often call them. Some are hard and others soft; some light, others heavy, and so on. Take, for example, a piece of stone. It differs very much from water; and water is not at all like air. In fact you cannot find two bodies that are exactly alike. Some, however, resemble others in many ways.

2. Solids.—Bread, wood, and stone are examples of what we call solid bodies; and they are so called, because they remain in the same form or shape without being held together by bottles, pails, or other things outside of themselves. All such bodies are spoken of as *solids*, even though they differ from one another in color, weight, and other properties.

3. Liquids.—Water, as we have said, is quite different from bread, wood, and stone. It yields readily when you touch it; and it does not remain in the same form, but flows or runs off in different directions, unless it is held together by something outside of itself; such, for example, as a pail, a pitcher, or the banks of a river. Milk is like water in this respect. It also has a tendency to flow in different directions.

Substances which resemble milk and water in their general properties are called liquid bodies, or simply *liquids*.

4. Gases.—Air, again, is very different from solid bodies,

and not at all like milk, water, or other liquids. It surrounds us at all times, and we breathe it constantly ; but it is so thin and light that we do not feel it, unless when it is in motion ; and it is difficult to confine or keep in one place, because of its strong tendency to fly off in all directions. Substances which resemble air are called gaseous bodies, or simply *gases*.

5. Chemical Affinity.—Chemical affinity is a force in substances which causes two or more of them to unite together in such a way as to form a single substance which differs entirely in its nature and properties from each and all of the substances uniting : as, for instance, the force which causes two gases (hydrogen and oxygen) to unite in such a way as to form water is called *chemical affinity ;* and it is chemical affinity which causes a greenish-yellow gas (chlorine) to unite with a light-colored metal (sodium), so as to make common salt. In such cases, the substances are said to be *chemically united*, and the single substance formed is called a compound.

6. Simple and Compound Substances.—Many bodies which appear to be made up of only one kind of substance are really composed of two or more substances chemically united ; and anything which can be split up into two or more essentially different substances is called *a compound substance*, or *compound body*, or simply *a compound*. Water, for example, can be split up into two well-known gases, which are quite different from each other ; and neither of them is at all like water. Hence we speak of water as a compound substance.

On the other hand, a substance which no one has been able to split up into other substances, and which, so far as we know, is made up of only one kind of substance, is called *a simple substance, an elementary body*, or *an element*. Iron and silver are examples of simple substances.

7. The Atmosphere.—The air which we breathe is commonly spoken of as the atmosphere. We all know something about it ; but there are not many of us who fully understand its properties. Without a knowledge of chemistry one would be apt to think that it is a simple gaseous substance ; and for hundreds of years all the best educated people were of that

opinion. Now, however, we know that it is not a simple substance, but a mixture of several gases.

These gases which make up the atmosphere are all of much importance in agriculture; and for that reason we shall give their names at once, and try to state, very briefly, a few of the properties of each.

(1) **Oxygen Gas.**—This is a colorless kind of air, or gas, which is so light and thin that we cannot feel it any more than we can feel common air; and we cannot see it; but it is a very abundant substance. It makes up a little more than one-fifth part of the atmosphere, nearly half of the solid earth, and eight-ninths by weight of all the water in the world. It is also very active in its nature, that is, it has a strong tendency to unite with other elements. Moisture or dampness causes it to combine with various substances (iron, for example) much more readily than it otherwise would; and heat acts in the same way, but with much greater effect. For instance, the heat produced by rubbing causes the oxygen of the air to unite very quickly and violently with the mixture on the end of a match, setting it on fire, as we say; while the greater heat of the burning match causes it to unite with paper, wood, and other substances.

When oxygen unites with any substance, it is said to *oxidize* that substance; and the action of uniting is called *oxidation.* If the action is so violent as to produce much heat, accompanied by light, we call it *burning* or *combustion;* and for that reason oxygen is said to support combustion.

Plants cannot live without oxygen; and animals die in a few minutes when deprived of it.

(2) **Nitrogen Gas.**—This also is a colorless gas, which has neither taste nor smell. Unlike oxygen, however, it has very little tendency to unite with other substances. It puts out burning bodies, such as a candle or a blazing splinter of wood; and animals die in it—not from any poisonous effects, but merely of suffocation, for want of oxygen. It makes up nearly four-fifths of the atmosphere, and is a necessary element in the food of all plants and animals.

Nitrogen may be obtained by burning a yellowish-white sub-

stance called phosphorus, under a jar, in a dish of water.   Place
the phosphorus upon a small
piece of broken plate or
saucer; lay this upon a flat
cork; and float the cork upon
the water.   Then putting a
match to the phosphorus, set
the jar over it, as in Figure
1; and the oxygen of the air
in the jar will unite with the

Fig. 1.

phosphorus, forming white smoke, or fumes.   These fumes will
gradually be dissolved or taken up by the water; and in the
course of a few hours almost pure nitrogen will be left in
the jar.

(3) **Carbon Dioxide, or Carbonic Acid Gas.**—When
several people have been for sometime in an ill-ventilated room,
the air in the room is found to be impure and oppressive.   Every
one has at some time or other felt the effects of such air; and
some may be interested to know that the unpleasant feelings
which it produces are caused chiefly by the gas *carbon dioxide*
(commonly called *carbonic acid gas*, or simply *carbonic acid*),
which is breathed from the lungs of those in the room.

Like oxygen and nitrogen, this gas, which is composed of
carbon (see section 17) and oxygen, is without color; and we
cannot see it; but its properties are very well known.   It is a
good deal heavier than air; it puts out burning bodies; and
animals die in it.

The amount of carbon dioxide in the air is very small com-
pared with the amounts of oxygen and nitrogen; but it is no less
important in its relations to agriculture.

(4) **Ammonia.**—In horse stables you have, perhaps, now
and then detected a strong pungent smell, the same as comes
from a spirits-of-hartshorn smelling bottle.   More or less of this
smell is found in all badly ventilated stables.   It comes both
from the urine of the animals and from portions of the manure
that are heating, and is caused by a light, colorless gas, called
ammonia.

Ammonia, as just stated, is a colorless gas. It is much lighter than air, and is quite soluble in water. One quart of water will take up as much as 700 quarts of ammonia. It furnishes nitrogen, an important element of plant food ; and its presence, unless in very small quantities, can be readily detected by the smell.

If anyone wants to test the smell of ammonia for himself, he has only to buy in a drug-store a small bottle of what is called *liquid ammonia*, that is, water with ammonia dissolved in it ; and two or three sniffs will give him a correct idea of the pungent smell here spoken of.

8. Composition of the Atmosphere.—In section 7, we said that the atmosphere is a mixture of gases ; and we have endeavored to give you some idea of the principal gases which are found in it, namely, oxygen, nitrogen, carbon dioxide, and ammonia.

The atmosphere contains all these gases : but it is made up chiefly of the first two—oxygen and nitrogen. The amount of carbon dioxide found in atmospheric air varies somewhat in different places ; but in the open country there are usually about 4 quarts of it in 10,000 quarts of air ; and the amount of ammonia is still less, being only about 1 quart in 1,000,000 quarts of air.

In addition to the four gases just named, the atmosphere contains some vapor of water and very small quantities of a substance called nitric acid ; also particles of dust and occasional traces of other substances.

Then, without trying to give a very exact statement, we may say that the composition of the atmosphere is as follows :—

Taking 100 quarts of air, we have

Oxygen.......................... ....about 21 quarts.
Nitrogen........................... ....about 78 quarts.
Carbon Dioxide, ⎫
Vapor of Water, ⎪
Ammonia, ⎬ together...............about 1 quart.
Nitric Acid, ⎭

100 quarts of air.

9. Food of Plants and Animals.—Everything that lives and grows must have food of some kind.   It is easy to see that common animals take food.   They have mouths for the purpose ; and most of them also have teeth with which to chew their food. Plants are quite different.   They are not provided with mouths like those of animals ; but they have roots and leaves which serve them instead.

Plants obtain their food from the soil and the atmosphere, eating, so to speak, some of the atmospheric gases and small quantities of the soil on which they grow.   They take these gases and soil substances in through their roots and leaves ; and, under the influence of sunlight, the leaves digest this food and use it so as to build up the plant in some way which we do not fully understand.

The food of *animals* (besides the water which they drink and the air which they breathe) is made up of plants, the seeds of plants, and the flesh of animals.   Cattle and horses, for example, live entirely upon grass, hay, and oats, or other plants. The lion and the tiger eat nothing but the flesh of animals, which they catch and devour ; while man likes a variety of both meat and vegetables.

10. Three Kingdoms.—The soil, stones, and rocks which make up the solid earth, and the water and atmosphere upon the earth, all taken together, are sometimes spoken of as *the mineral kingdom ;* the trees, herbs, and other plants on the earth, as *the vegetable kingdom ;* man, beasts, birds, fishes, and all other animals, as *the animal kingdom :* and it is interesting to notice how closely these three kingdoms are related to one another.   The vegetable kingdom is clearly dependent upon the mineral kingdom, because plants grow by using mineral matter which they get from the soil and the atmosphere ; and the animal kingdom is equally dependent upon the vegetable kingdom, since the food of animals is all furnished directly or indirectly by plants.

Further, the leaves of plants take in carbon dioxide from the atmosphere and give out more or less oxygen.   Animals do the very opposite.   Every time they breathe they take in oxygen

and give out carbon dioxide. Thus, by a wise provision of the Creator, the animal and vegetable kingdoms are so related to each other that the one is constantly supplying what the other uses and using what the other supplies.

CHAPTER II.

The Plant.

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11. Plants as Living Things.—Objects in the mineral kingdom, such as stones, earth, and water, are entirely without life, and undergo very little change from year to year. With plants it is quite different. They are living things, and, like animals, go through the stages of youth, maturity, and old age. They, of course, differ from animals in many particulars, especially in not being able to move from one place to another.

Some plants live for a short time, flower but once, and die soon afterwards. Of these there are two classes: *annuals*, like wheat, oats, and barley, which live only one year or season ; and *biennials*, such as turnips, beets, and cabbage, which last for two years. Other plants, called *perennials*, live for many years and flower periodically during their life. Maples, lilacs, and common grasses, are familiar examples of perennial plants.

12. Things Necessary to the Life of Plants.—In order that plants may live and grow, it is necessary that they have *air, moisture, warmth, light,* and a small amount of *earthy matter.*

Some plants need much more moisture than others ; and the warmth which plants require varies from a high temperature down almost to the freezing point. As regards light also there is a difference. Most plants need abundance of sunlight ; but some fungi, such as blue-mould, are known to grow in almost total darkness. Seeds, tubers, and bulbs, as peas, potatoes, and

onion sets, grow when covered up in the ground ; but they are
not exceptions to the general rule regarding light, because their
growth in the dark continues only so long as they are using
material which is stored up in themselves. When that is all
used, the young plants must have light, or they will languish and
die.

13. Forms of Plants.—There is an endless variety in the
forms of plants. Trees, shrubs, and common herbs, as maples,
lilacs, and grasses, are familiar to us all ; but such plants make
up only a small part of the vegetable kingdom. In addition to
these, we have the beautiful mosses which carpet the forest, the
slimes found in stagnant water, the blue-mould on cheese, the
rust on wheat, and a vast number of others—all plants of a low
order, and many of them so small that a microscope is necessary
to reveal their varied forms.

14. Primary Divisions of Plants.—Plants are com-
monly divided into two main divisions, or groups—

(1) *Flowering plants*, to which belong trees, shrubs, and
common herbs.

(2) *Flowerless plants*, such as ferns, mosses, sea-weeds,
mushrooms, smut, rust, etc.

Plants of the first division have flowers, and produce seeds
which contain each a very small young plant called the *embryo*.
If, for example, a pea is soaked in water till it splits open, the
tiny plantlet can be plainly seen lying between the lobes of the
seed. Plants of the second division have neither flowers nor
seeds ; but they produce in their leaves or bodies very small
germs, called spores, which do not contain embryo plants, but
nevertheless grow and take the place of true seeds.

15. Principal Parts of Plants.—These are the *root*, the
stem, the *leaves*, and the *flower*. The flower produces *seeds* ;
and the seeds are sometimes enclosed in a fleshy substance called
fruit, as in the case of apples, cherries, and plums.

Most flowering plants have roots. They all have stems,
generally of considerable length, though sometimes very short.
Some few (such as dodder), which feed on the juices of other
plants, are without leaves : but they all have flowers of some sort.

16. Structure of Plants.—By the use of the micro-scope we learn that plants are made up of small sacs called *cells,* and of tubes, which are also very small and commonly known by the name of *vessels*—all closely packed together.

Young growing cells consist of very small masses of a soft substance resembling the white of an egg, each enclosed in a little sac, which is made by the soft substance, pretty much as a snail makes its shell ; and, as regards the form of cells, we may say that at first they are round or nearly so, as in Figure 2 ; but in the process of growth they assume various shapes. Sometimes they are quite

Fig. 2. Plant Cells.

long and tough, as in flax and hemp ; and in many plants they become very hard, as in various kinds of wood. New cells are formed more or less rapidly wherever growth is taking place ; and when spoken of collectively, they are called *cellular tissue,* that is a tissue or fabric made by weaving or build-ing cells together.
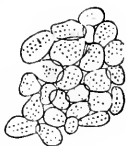
Fig. 3. Vessels.

Vessels are formed out of rows of cells placed one upon another and having the walls which separate them removed by absorption. They vary a good deal in size, and are marked in different ways by deposits of matter on the inside of their walls, as shown to some extent in Figures 3 and 4.
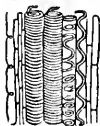
Fig. 4. Bundle of Vessels.

17. Composition of Plants.—The substances found in plants may be classified under several heads, a few of which are as follows :—

(1) **Water and Dry Matter of Plants.**—The amount of water in any plant will vary somewhat according to the tempera-ture and dryness of the atmosphere and the soil ; but living plants under all circumstances contain a much larger weight of water than of any other substance. In many vegetables and roots, such as lettuce and turnips, there is as much as 90 per cent. of water, that is, 90 ℔s. of water in 100 ℔s. of the plant ; and trees cut in the driest time seldom contain less than 40 per cent. of water.

When a plant is cut and dried in the air, it loses a large part of its water. Timothy, for instance, when fresh cut, contains about 72 per cent. of water ; and, when made into hay, it contains only about 15 per cent.

To remove all the water of a plant, it is necessary to keep it for some hours (perhaps a couple of days) in an oven or elsewhere, at a temperature of about 212 degrees Fahrenheit, that is, at or a little below the temperature of boiling water. If the temperature were higher, the plant would burn.

When the water is all removed from a plant by drying as above, the part that remains is called the *dry matter* of the plant.

(2) **Elementary Substances in Plants.**—Chemists tell us that earth, air, water, plants, and the bodies of animals, are all made up of simple, or elementary, substances, mixed together or chemically united. They have discovered 65 such substances —two of them being liquids, five of them gases, and all the rest solids. Mercury (a liquid), oxygen (a gas), and iron (a solid), are familiar examples of these substances.

There are four elementary substances in the atmosphere ; two (hydrogen and oxygen), when chemically united, make water ; and the whole 65 have been found in the earth.

So far as we know at present, the elementary substances necessary for the growth of plants are ten in number, and their names are as follows :

Carbon . . . . a dark colored solid—charcoal, for example.

Hydrogen . . . . . . a very light, colorless gas.

Oxygen . . . . a colorless gas.

Nitrogen . . . . . . a colorless gas.

Sulphur . . . . . a yellowish solid.

Phosphorus . . . . a yellowish-white solid.

Potassium . . . . . a silver-white solid.

Calcium . . . . . . a light, yellowish solid.

Magnesium . . . . a silver-white solid.

Iron . . . . a silver-gray solid.

3 gases and 7 solids.

It has been proved by experiment that most, if not all, plants will grow and mature fully where they get a suitable supply of

these ten elements alone, but not where any one of them is wanting. In addition to these, however, *soda, silica, chlorine,* and traces of a few other substances, are found in most plants grown on the farm ; but none of them are essential to plant growth.

(3) Combustible and Incombustible Parts of Plants.

When a piece of wood is burned, the greater part of it is consumed and disappears altogether. It is not destroyed, however, but only goes off as gas into the atmosphere. That part of plants which thus burns away in the fire is called the *combustible part ;* and the white ash which remains is called the *incombustible part.*

The combustible part is usually about 95 per cent. of the dry matter of plants, and is composed of the first five elementary substances given above under (2), namely : *carbon, hydrogen, oxygen, nitrogen,* and *sulphur.* Carbon usually forms about 50 per cent. of the dry combustible part of plants, nitrogen $\frac{1}{2}$ to 4 per cent., and sulphur generally less than 1 per cent.

The incombustible part (known also as ash or mineral matter), which is all obtained from the soil, varies considerably in different plants and in different parts of the same plant ; but on the average it is not more than about 5 lbs. in 100 lbs. of the dried plant. There is less of the ash constituents in seed than in any other part of crops, more in straw, and most in leaves, especially old leaves. The ash obtained from burning turnip tops, potato tops, and cabbage leaves, is from 10 to 25 per cent. of the dry matter. Hence when these tops or leaves are taken off the land, a large amount of plant food is removed. This part of plants, that is, the incombustible part, always contains the second five elements given under (2), that is, *phosphorus, potassium, calcium, magnesium,* and *iron,* besides a little sulphur. The amount of iron is very small, and the quantities of phosphorus, potassium, etc., vary a good deal in different plants. Two or three other substances are also found in the incombustible part, but none of them are essential or in any way necessary to the growth of plants.

(4) Organic Compounds in Plants. The ten substances

given under (2) do not exist in the plant as independent elements, but are united by chemical affinity and the vital forces of the plant into a large number of compounds. These compounds which are formed in the growing plant are commonly called *organic compounds*; and some of them are of much value as constituents of food for animals.

It is impossible to describe these compounds without using some long and difficult words which most young people do not understand; but we must nevertheless refer very briefly to a few of them, because of their importance in cattle-feeding. Those organic compounds which contain nitrogen are called *nitrogenous substances*, and those in which there is no nitrogen are sometimes spoken of as *non-nitrogenous substances*.

(*a*) **Nitrogenous Substances.** Of these there are at least three kinds; but the most important are those which are known as *albuminoids*. The word *albumen* is a name given to a nitrogenous compound which makes up the greater part of the white of eggs; and from it all similar nitrogenous compounds in plants and animals are called albuminoids. These compounds exist dissolved in the sap of plants and make up a large part of the bodies of animals; and when the water associated with them in the plant or animal is driven off by evaporation, they appear as colorless or yellowish solids.

We may add that albuminoids are sometimes called flesh-forming substances, or simply *flesh-formers*, because of their use in producing the flesh and muscle of animals; and they are all composed of the first five elements given under (2), viz., carbon, hydrogen, oxygen, nitrogen, and a little sulphur; but they vary slightly in composition and are known by different names in the different plants and substances in which they are found. The albuminoid or mixture of albuminoids in peas is called *legumin*; in wheat, *gluten*; in blood and flesh, *fibrin*; and in milk, *casein*. The quantity of albuminoids in plants varies from about 2 to 34 per cent.

Two other classes of nitrogenous substances, found in plants, are called amides and alkaloids. The nature of *amides* is not well understood; but they are known to exist more or less abun-

dantly in roots and immature plants, especially in the green parts of plants, where growth is vigorous and new matter is being formed. *Alkaloids* are known for the most part either as valuable medicines or deadly poisons; such as quinine, obtained from the bark of a tree; morphine, from the poppy; nicotine, from tobacco; and strychnine, from the St. Ignatius bean and other plants.

(*b*) **Non-Nitrogenous Substances.** Of these the most important are cellulose, starch, sugar, fat, oil, and vegetable acids. We have not space for a full description of these substances. A few words about each will perhaps serve the purpose.

Cellulose is a fibrous substance which forms the skeleton or framework of plants and gives them strength, stability, and roughness. Next to water it is the most abundant substance in plants. Well-ripened wheat straw, for example, is nearly all cellulose. When cellulose is well matured and hard, as in the straw of cereals and the stalks of ripe timothy and clover, we call it woody fibre.

Starch is a fine white powder, well known as laundry starch, corn-starch, etc. It forms four-fifths of the substance of dried potatoes, and rather more than half of Indian corn meal, wheat flour, rye flour, etc. Next to water and cellulose, starch is the most abundant substance in plants as a whole, while some plants contain a much larger proportion of it than of cellulose.

Sugar is a well-known, sweet-tasting, very soluble substance, which is found in all plants and exists largely in sugar cane, in the sap of maple trees, in beets, parsnips, and all kinds of fruit.

Gum is a transparent substance, which, when dissolved in water, generally becomes sticky and forms a mucilage. Gum Arabic is a familiar example.

Fat is a solid greasy substance of a white or yellowish color, which contains a much larger proportion of carbon and hydrogen than is found in starch or sugar; and for that reason, as an ingredient of food, it is considered worth two and a half times as much as starch or sugar. The fat of plants is most abundant in the seed, as in flax-seed, cotton-seed, etc.; and it differs very little from animal fat, such as lard, tallow, and suet.

Oil is a fat which remains liquid at ordinary temperatures, as linseed oil and olive or sweet oil.

Vegetable Acids are very numerous. Some of them are found in all classes of plants; and nearly every family of plants contains acids peculiar to itself. They are all intensely sour. They exist dissolved in the juices of plants, as in green apples, cherries, etc.; but when the water in the juices is removed by evaporation, they appear as solids, generally as white or colorless crystals. The most common are *oxalic, malic, tartaric,* and *citric* acids.

18. Carbo-Hydrates.—In books on cattle-feeding we find cellulose, starch, sugar, gum, and a few less important compounds spoken of as *carbo-hydrates* (carbon-and-water compounds), from the Latin *carbo*, carbon, and the Greek word, *hydōr*, water; and they are so called, because the carbon has hydrogen and oxygen united with it in the proportion which is necessary to form water.

The fat of plants and the carbo-hydrates taken together make up what may be called the heat-and-fat producing constituents of food.

19. Nature and Sources of Plant Food.—Plants can use their food only when it is in the gaseous form, like air, or is dissolved in water. No matter how much a plant may need food, it cannot take up solid substances from the soil. It is dependent upon what it gets from the atmosphere and upon those portions of the soil which are dissolved by water and by certain juices which come out through the surface of the little rootlets as they force their way through the soil.

Hence we may say that plants obtain their food partly from the soil and partly from the atmosphere. *From the soil* they obtain, by means of their roots, all their ash constituents (the incombustible part), all their sulphur, and nearly the whole of their nitrogen and water. *From the atmosphere* they obtain, through their leaves, the whole, or nearly the whole, of their carbon, with probably small quantities of nitrogen and water.

20. Seed of Plants.—If we put a few peas or grains of wheat with a little warm water into a cup or saucer and let them

stand till they become soft and somewhat swollen, we shall find that each seed has an outer covering, or seed-coat, and within this coat a very small plant called the *embryo*, or *germ*, and a certain amount of starchy or fatty matter stored up as food for the embryo. In a similar way it may be shown that every true seed contains a little plant and a store of food intended to nourish this plantlet until it takes root in the ground and sends up its leaves above the surface of the soil.

In the seeds of cereals (wheat, oats, barley, rye, etc.) and of many other plants, the chief ingredient is *starch*. In another class of seeds, such as linseed and mustard seed, there is no starch, but in its place a large amount of *fat*. We find also a much larger proportion of *albuminoids* in the seed than in any other part of the plant; and the ash obtained by burning seeds is rich in two important substances which will be explained in the next chapter, namely, *phosphoric acid* and *potash*.

21. Germination of Seeds.—By germination we mean the growth of the embryo in a seed; and we shall try to explain very briefly how it takes place. No matter where a seed is sown, it will not grow, unless it has moisture, air, and warmth. We sow seeds in the ground, because the plants which grow from them are dependent upon the soil for a part of their food; but seeds would germinate anywhere else almost as well, if they had the necessary moisture, air, and warmth.

When a pea or a grain of wheat, for example, is placed where it gets moisture, air, and warmth, it swells and becomes soft; oxygen is absorbed from the air, the starch and oil of the seed are changed into sugar, and other chemical changes take place. The embryo,
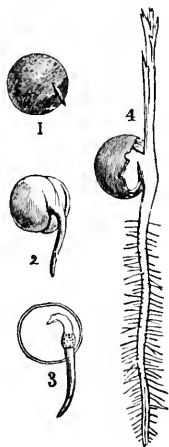

Fig. 5. A pea at different stages of germination; 3, having one lobe removed, shows the plumule beginning to develop.

feeding upon the sugar and other substances in the seed, grows so fast that, in a few days or hours, one end of it, called the *radicle*, or little root, forces its way through the seed-coat (as shown in Figures 5 and 6) and produces one or more regular plan. roots, which spread out or go deeper into the ground; and the other end, called the *plumule*, because of its supposed likeness to a little feather, grows upwards to the light till it produces a leaf or leaves above ground, after which it gets its food from the soil and the atmosphere, like older plants.
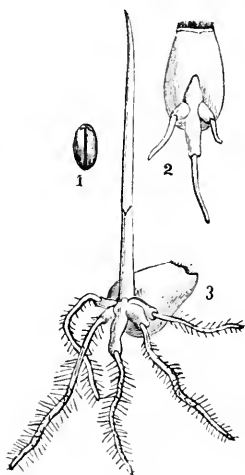

Fig. 6. 1, a grain of wheat; 2, back view of same (enlarged) beginning to grow; 3, the young plant at a later stage.

Seeds buried too deeply in the soil may fail to germinate for want of air; or, if germination takes place, the store of food in the seed may be all used before the plumule reaches the surface. If so, of course, the plantlet will die in the ground. As a rule, the smaller the seed, the less the depth of earth with which it should be covered.

22. Growth of Plants. — It would be necessary to write a whole book in order to explain fully how plants grow; and in a section like this we can merely refer to two or three of the most important points.

The leaves of plants freely absorb the gas carbon dioxide (carbon and oxygen) from the atmosphere; and, under the influence of sunlight, with a certain amount of heat, the green matter of the leaves, commonly called *chlorophyll*, breaks up this gas, giving back the oxygen to the atmosphere and using the carbon to build up the plant. We cannot state exactly the changes which take place in this breaking up of carbon dioxide; but we know that in most plants the whole or part of the carbon unites with the elements of water (hydrogen and oxygen) in such a way that starch is formed in the leaves.

The starch made in the leaves is insoluble; but by the forces at work in the plant it is gradually changed into sugar, or other soluble compounds very like sugar, and distributed throughout the plant, to be used wherever growth is taking place.

Starch-making in the leaves begins as soon as the young plant forces its way through the surface of the soil; and at the same time a part of the water which the plant contains commences to evaporate, or go off as invisible vapor, from all parts of its surface, but especially from the large number of pores, or openings, in the under side of the leaves. The amount of water which plants lose in this way is large; and it has to be replaced by fresh supplies from the soil. Hence land on which a crop is growing or has grown is always much drier than a bare fallow.

This evaporation from the leaves assists in causing an upward movement of the sap in the plant, pretty much as water rises in a pump. Thus the substances taken up by the roots are distributed throughout the stem and the branches; and the growing cells use them along with the starch-products (sugar, etc.) from the leaves, in such a way as to build up the plant.

24. Methods of Plant Development.—In an *annual plant*, which lasts for only one year or season, there is first, with more or less of stem, a large development of roots and leaves, which collect and prepare food for future growth; next, there is the formation of flowers; and, lastly, the production of seed; after which the plant dies. Wheat, oats, and peas, are familiar examples of this class of plants.

In *biennial plants*, which last for two years or seasons, the growth of root and leaf is much the same as in annuals; but towards the end of summer and during the autumn of the first year there is a storing up of elaborated plant food (starch, albuminoids, etc.) in the root or stem, to be used by the plant in the following spring. Beets, carrots, turnips, mangels, and cabbage, are common examples of biennial plants; and any of them will serve to illustrate the method of biennial plant growth. In the case of the turnip, for instance, the root grows to a large size in the fall; and late in the season, when growth is at an end, the leaves wither or die, after transferring most of their

valuable constituents to the root.   The root, whether it is pulled or remains in the ground, lives throughout the winter.   In the following spring it begins to grow again ; and, by using the food stored up in itself, it sends up a flower stem and produces flowers and seed ; after which the plant dies.

In *perennial plants*, which last from year to year, a store of food is laid up annually towards the end of summer and in the early part of autumn, to serve for the commencement of growth in the following spring.   In common trees, such as the oak or the maple, a reserve store is deposited in the pith, the pith rays,* and the layer between the bark and the wood ; and by the action of the sun in springtime this reserve material is made available for the growth of leaves, shoots, and new wood.   The sugar of maple sap, for instance, comes from the transformation of starch which was stored up the preceding summer and autumn.

25. Effects of Seed Formation.—When the seed begins to form, an exhaustion of the other parts of the plant sets in, especially in annual and biennial plants.   Starch, albuminoids, and other valuable substances, are then transferred from the root, stem, and leaves, and stored up in the seed ; and at the same time there is a change of substances in the stem from a digestible to a comparatively indigestible form—from carbohydrates (starch, sugar, etc.) into crude, woody fibre.   The straw of well-ripened wheat and peas, for example, is thus to a large extent exhausted of its most valuable food materials ; and for that reason, hay (clover, timothy, etc.) which is allowed to stand till the seed forms is much injured in quality.   As a general rule, plants which we intend to cure and use for fodder, should be cut when they are in full bloom, as the seeds are just beginning to form.

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*The lines of cellular tissue which, in common trees and shrubs, extend from the central pith out to the bark.

CHAPTER III.

The Soil.

26. Terms Explained.—Before proceeding to speak of the soil, we must explain very briefly a few chemical terms which it is necessary to use in this chapter.

(1) *Sulphuric acid*, containing sulphur ; *nitric acid*, containing nitrogen ; and *phosphoric acid*, containing phosphorus—are all sour liquids ; and the first two are poisonous.

(2) These acids unite with metals, such as iron, potassium, etc., forming compounds which are known as *sulphates, nitrates,* and *phosphates ;* and the word *salt* is a common name applied to all such compounds of acids and metals.

(3) An *oxide* is a compound substance formed by the union of oxygen with some other element. The oxide of potassium is called *potash ;* that of calcium is called *lime ;* of magnesium, *magnesia ;* of sodium, *soda ;* of silicon, *silica :* and in giving the composition of plants, soil, and manures, we use the terms potash, lime, magnesia, silica, etc., instead of the names of the elements.

27. What Soil is.—Soil is that part of the ground which can be tilled (plowed, harrowed, etc.), and in which plants grow. It varies in depth from a few inches to several feet ; but good soils in this Province are usually from ten to fifteen inches deep.

28. Meaning of the Term "Subsoil."—The subsoil is the layer of earth beneath the soil. It is generally more compact than the soil, contains less organic matter (decayed roots, leaves, etc.), and is of a lighter color. In many places, a part of the subsoil may be gradually changed into soil by under-draining and deeper plowing.

29. Origin of Soil and Subsoil.—Soil and subsoil are produced in the first place by the disintegration, or breaking up, of rocks ; and the character of both depends very largely upon the composition of the rocks from which they have been formed ;

some rocks, for instance, being rich in phosphoric acid, others containing a large amount of potash, and so on.

30. Formation of Soil.—Soil, as we now have it, has been made from rocks chiefly through the agency of air, frost, and water ; while its character has been more or less influenced by the growth of plants, the burrowing of earth-worms, and the remains of plants and animals. We have not space to explain fully how these different agencies have operated in producing various kinds of soil ; but a few words about each may help us to understand something about soil formation.

(1) **Air.**—The oxygen of the air, acting upon rocks that are exposed to it, unites with some of the substances which they contain, as iron, etc., and thereby causes a gradual decay of rock material. Some of the compounds thus formed by oxygen, being soluble, are dissolved or washed out by water ; and their removal causes portions of the surrounding rock to crumble into insoluble dust, or soil. We may add, however, that dry air alone has not much effect on most kinds of rock. It is only in connection with water and carbonic acid that it acts in the way described above.

(2) **Frost.**—When water freezes it swells out, or, as we usually say, expands, with great force. So great is this expansive force of freezing water, that it often bursts strong iron pipes and causes serious trouble in houses which are not proof against frost. Bearing this fact in mind, we can understand how it is that, in moist and temperate climates, frost disintegrates rocks ; because water lies in hollow places on the rocky floor, soaks into porous parts, and runs into cracks. At certain seasons of the year this water freezes ; and, in doing so, it expands with such force that it breaks off portions of the surrounding rock. In this way, by successive freezing and thawing, rock material is gradually changed into soil, and the soil is pulverized, or made fine, from year to year, especially those parts of it which are turned up by plowing in the fall.

(3) **Water.**—Rain, falling through the air, carries with it more or less oxygen and carbonic acid ; and water containing these substances does more than perhaps anything else to

dissolve and break up rocks, especially limestone and felspar. The action of rain-water upon rocks containing lime arises chiefly from the solvent power of the carbonic acid which it absorbs from the atmosphere ; and its power to break up the felspars (rocks which yield potash) is due to both the oxygen and the carbonic acid which it contains. Water acts also by washing off the fine particles of rock which have been set free, and carrying them from higher to lower ground.

(4) **Plants.**—Plants affect rock both in their growth and in their decay. The lower orders of plants—mosses and such like —grow upon rocks which have scarcely any covering of earth ; and, spreading over the surface, they keep the rock moist and thus promote disintegration. At the same time, the roots of growing plants penetrate the partially decayed rock material, and, by means of the acid juices which they contain, dissolve minute portions of it, thereby assisting in the further breaking up and preparation of that material as food for further plant growth. But the effects of decaying vegetable matter are still greater. Such decaying matter absorbs much moisture and keeps everything about it damp ; and it yields a constant supply of carbonic acid gas, which, being absorbed by rain-water, is carried down through the soil and thus enabled to act upon the mineral matters below. The decay of vegetable matter also produces certain organic acids, which assist in the work of disintegration.

(5) **Earth-Worms.**—The character of soil is also affected more or less by earth-worms and other earth-dwelling creatures. The burrowing of worms, especially, brings fresh particles of earth to the surface, and opens passages by which air and rain-water reach the subsoil. In this way the subsoil is improved, and the surface soil, being worked over and in a sense digested, is better fitted for the growth of crops than it otherwise would be.

31. Composition of Soil.—The principal constituents of ordinary soil are—

> Sand,
> Clay,
> Humus,

The first two of these—sand and clay—make up more than 90 per cent. of the dry substance of most soils in this country ; and the amount of humus, or organic matter, in soil varies from about 3 to 7 per cent.

32. Sand.—Pure sand consists almost entirely of small grains of *silica* (see section 26), which is well-known by the name of quartz ; but grains of lime, mica, and other substances, are sometimes mixed with the silica, forming special varieties ; such, for example, as calcareous (limy) and micaceous sands.

Pure sand is not plant food. Plants do not use it ; but it is nevertheless a very important constituent of soil. It is insoluble in water and in most acids ; and the particles of which it is composed have little or no tendency to stick together. Hence, acting as a divider of the other constituents of soil, it makes land easy to work and facilitates the passage of roots in search of food. It absorbs very little moisture from the atmosphere, and has not much power to hold either water or fertilizing material ; but it readily absorbs heat, which it retains much longer than do any of the other constituents of soil. Capillary attraction, which causes water to rise from the subsoil through the pores of the soil above, has but little effect in the coarser kinds of sand.

From these facts, it is evident that soil containing much sand will be loose, easy to work, dry, warm, and free from "baking," but apt to suffer from drought at certain seasons of the year, and to lose soluble plant food by leaching, especially when the subsoil is sand or gravel.

The amount of sand in soil varies all the way from 8 or 10 to more than 90 per cent. ; and, generally speaking, the finer kinds of sand are better for agricultural purposes than the coarse varieties.

33. Clay.—Pure clay is a compound of silica and a substance called alumina. It is, however, very seldom pure. It nearly always has potash, lime, ammonia, etc., mixed with it ; and portions of these impurities, or some of them, combine with the clay, forming important compounds which are known as *double silicates ;* such, for example, as silicate of alumina and potash, or silicate of alumina and lime ; which are valuable because of the potash, lime, etc., which they furnish to plants,

Clay is not plant food. It is not taken up by plants, except by a few of the lower orders ; but most of the impurities found in it, as potash, lime, magnesia, and iron, are necessary for plant growth. Red clays always contain iron ; and most clay soils are naturally rich in potash.

Clay is of extremely fine texture ; and the particles of which it is composed have a strong tendency to stick together. Hence clay gives "body" and stiffness to soils. It possesses also in a high degree the power of absorbing moisture and ammonia from the atmosphere, and of retaining water, ammonia, phosphoric acid, and other substances necessary for the growth of plants. Clay absorbs heat readily (more readily than sand) ; but owing to its persistent retention of moisture, it is naturally very cool : and capillary attraction produces its full effect in bringing water up through clay soils, especially when they are well underdrained and thus saved from cracking, as undrained clay is apt to do in dry weather.

To sum up, we may say that land containing much clay is usually rich in plant food, is strongly retentive of moisture and manure, and is cool and good to resist drought ; but it is hard to work, and, when not properly drained, is apt to be wet and cold in fall and spring, and to bake and crack in summer. Hence the necessity for draining clay soil.

The amount of clayey substance (clay, iron, rock-dust, etc.) in soil varies from about 10 to nearly 90 per cent. ; but the quantity of pure clay in even the heaviest clay soils rarely exceeds 30 per cent. of the dry substance.

34. Humus.—By the term "humus," we mean decayed or partially decayed vegetable matter—often spoken of as *the organic part of soil*. It is of a dark-brown or black color, and comes from the rotting of plant-roots, leaves, stubble, weeds, grass, barnyard manure, etc., in and upon the soil. Well-rotted leaf-mould is a good example of humus. The chief constituent of humus is carbon ; but it contains all the other substances found in plants, and by its gradual decay these substances are, little by little, made available for plant food. Humus is *the chief source of nitrogen in soil.* "A black soil, rich in humus,

is sure to be rich also in nitrogen. The fertility of virgin (or new) soils is largely due to the nitrogenous humus which they contain"; and the decomposition of humus in the soil produces a constant supply of the gas carbon dioxide, which, being dissolved in the water of the soil, assists in breaking up its mineral matters and making them ready for the use of plants.

Of all soil ingredients, humus has the greatest power to absorb and retain moisture, and to draw water from the subsoil by means of capillary attraction. Hence it helps soils to withstand drought. It also possesses in a high degree the power to absorb ammonia from the atmosphere, and to retain it and various other fertilizing substances; and, partly by its dark color (see section 48) it adds to the warmth of soil in day-time, while by cooling quickly at night, it assists very much in causing dew to be deposited upon and within the soils that contain it.

Humus also improves the texture of soils by making clay soil more friable, and sandy soil more compact and retentive.

The amount of humus in different soils varies very much. It is most deficient in sandy soils and poor clays. Some fertile soils contain less than 2 per cent. of humus, and the alluvial soils of the Nile contain only about 5 per cent.; but many other good soils contain as much as 10 per cent., while rich vegetable moulds and peaty soils contain a much larger proportion. It is said that "oats will grow on land containing only 2 per cent. of humus, barley on land containing 3 per cent., and wheat on land containing 4 per cent." So, all things considered, we may say that the amount of humus in fertile soils is usually from about 3 to 7 or 8 per cent.

35. Constituents of Soil as given by Chemists.—

Speaking in the language of chemistry, we may say that, apart from the organic matter, soil is composed of the following substances:

Silica,	Oxide of Iron,
Alumina,	Magnesia,
Phosphoric Acid,	Sulphuric Acid,
Potash,	Soda,
Lime,	Chlorine,

Traces of other substances.

The first two of these substances have already been referred to and need no further description; but we may add that the silica which plants take up from the soil is not ordinary sand or quartz, but probably a part of that which is combined with alumina in some variety of clay (see section 33). The other substances in this list are found in very small quantities in most soils. In some places, lime and iron are abundant. Generally speaking, however, they do not exceed 3 or 4 per cent. each of the dry substance of soil ; and very often the percentage is not half this amount.

36. Nitrogen in Soil.—The nitrogen of soil is for the most part contained in the humus which has accumulated in the course of time from the growth and decay of plants (roots, leaves, weeds, grass, etc.) in or upon the ground, and from the farm-yard manure which has been applied in some places. Another source of soil-nitrogen is the " aqueous deposits," that is, the rain, dew, and snow, which collect and bring down from the atmosphere every year from 5 to 8 or 10 lbs. of nitrogen per acre, in the form of ammonia and nitric acid.

The quantity of nitrogen in soil varies very much at different times according to temperature, rain-fall, and the texture of the soil, as will be explained in sections 44 (3), 45, 46, and 47 ; but the amount is always small, being about $\frac{1}{4}$ to $\frac{1}{2}$ per cent. in good rich soil and perhaps $\frac{1}{20}$ per cent. in clay subsoil.

37. Phosphoric Acid in Soil.—Phosphoric acid is found in all good soils, but only in small quantities, varying from about $\frac{1}{5}$ to 1 per cent. The average amount is probably $\frac{1}{2}$ per cent. or less; and it exists in soil, not as a separate substance, but united with lime, iron, etc., and generally occurring as a well-known mineral called apatite, or phosphate of lime.

38. Potash in Soil.—Potash also is an essential constituent of all fertile soils. It does not exist separately in the soil, but is combined with other substances, usually forming part of a compound which is known as the double silicate of alumina and potash (see section 33). It varies in quantity from mere traces up to 1 or 2 per cent., being most deficient in sandy, peaty, and marly soils, and most abundant in clay.

39. Lime in Soil.—By the term "lime" we mean the oxide of calcium (see section 26)— sometimes called *quicklime*, because of its active burning properties. It readily unites with water; and the compound formed by the union of lime and water is called *slaked lime*, or *hydrate of lime*. In soil it nearly always occurs as carbonate of lime, or common limestone, varying from mere traces up to a large percentage. In certain localities it occurs as phosphate of lime, or apatite. It is found also as sulphate of lime, or gypsum, which, when ground up, is called "land-plaster," and when heated becomes a fine white powder known as plaster of Paris. Clay loam usually contains from 1 to 3 per cent. of lime; and less than one per cent. of lime in soil is considered too little.

In power to hold water, lime is between sand and clay, holding more moisture than sand and less than clay; and, like humus, it improves the texture of soil by making clay soils more friable and sandy soils more compact and retentive. It also promotes the decomposition of vegetable matter and the formation of nitrates in the soil (see section 26).

40. Most Important Constituents of Soil.—Sand, clay, humus, and the various elements of plant food, are all important constituents of soil; and when any one of them is deficient, it is then and for that soil the most important constituent; but the substances which are most frequently deficient, which are soonest exhausted by bad farming, and which produce the most marked effects when applied as manures,—are available *nitrogen, phosphoric acid,* and *potash.* Hence these substances are in a sense the most important constituents of soil.

41. Classification of Soils.—There are several ways in which soils may be classified; but the simplest and most convenient classification seems to be that which is based on the relative proportions of sand and clay. Taking these two substances and omitting the rest (because they occur only in small quantities), we have the following table, which may be regarded as a general, though not very exact, classification of soils:

Name of Soil.	Percentage of Sand.	Percentage of Clay. (Or, more correctly, clay, rock-dust, etc.)
Sand	80 to 100	20 to 0
Sandy loam	60 to 80	40 to 20
Loam	40 to 60	60 to 40
Clay loam	20 to 40	80 to 60
Clay	10 to 20	90 to 80

Soils that contain much lime (say 20 per cent. or more) are called calcareous soils; and those in which there is a large amount of organic matter are known as peaty soils, vegetable soils, or vegetable moulds. Soils are also spoken of, from their texture, as being light or heavy, porous or impervious; from their relations to heat and moisture, as cold or warm, wet or dry; and from the extent of their fertility, as rich or poor, fertile or infertile, barren, etc.

42. Light and Heavy Soils.—The terms "light" and "heavy," as applied to soils, are apt to be misunderstood. They refer, not to the actual weight of a soil, but to the degree of its tenacity or "stickiness." In the farmer's sense of the word, sandy soils are the lightest of all, because they are very porous and easy to work, while in actual weight they are the heaviest soils known. Clay, on the other hand, is spoken of as a heavy soil, because it is tenacious and hard to work, though in weight it is much lighter than sand. Peaty soils are light in both senses, being very porous and having but little weight. In actual weight, sand is the heaviest and humus the lightest constituent of soil.

43. Plant Food in Soil.—Sand, clay, and humus, which form about 95 per cent. of most soils, give body to soil and serve as a covering for plant roots. These constituents also hold the elements for plant nourishment and furnish the necessary conditions as to heat and moisture—they form, so to speak, the hunting-ground in which plants search for what they require; but, excepting a little of the humus, they are not themselves plant food. The substances on which plants feed, all taken together, are only a very small part of the most fertile soil; but the weight of soil is so great that even a very small fraction of

plant food amounts to a large number of pounds per acre. According to Warington, the surface of an acre of clay loam, to a depth of 9 inches, when perfectly dry, weighs from three to three and a half million pounds (3,000,000 to 3,500,000 lbs.). Taking this as a correct estimate, we find that $\frac{1}{7}$ per cent. of nitrogen, $\frac{2}{5}$ per cent. of phosphoric acid, and $\frac{1}{2}$ per cent. of potash, yield as follows :

Nitrogen .... 4,286 to 5,000 lbs. per acre.
Phosphoric acid .... 12,000 to 14,000 "   "
Potash .... 15,000 to 17,500 "   "

44. Active and Dormant Constituents of Soil.—Not more than perhaps one per cent. of the substance of soil, even the most fertile soil, is at any time in such a condition that plants can make use of it. The greater part of the plant food in soil is quite insoluble, and cannot be used by plants till it undergoes some chemical change. Hence a soil may contain several thousand pounds per acre of nitrogen, phosphoric acid, and potash, and all the while be unproductive. For that reason chemical analysis alone is not generally sufficient to decide whether a soil will produce good crops or not ; because it merely tells how much of each substance is present, without making known what proportion of it is in a fit condition to nourish plants.

Those portions of plant food which are (at any given time) available for the use of plants are sometimes called the *active constituents* of soil; and those compounds which (at that time) are insoluble in water or dilute acids, and therefore incapable of being taken up by plants, are often spoken of as the *dormant constituents*, that is, the sleeping or inactive portions which serve only as stores of food for future use.

Most of the soils in this Province contain plant food enough to produce crops for generations to come, if we only treat them in such a way as to change from year to year a sufficient amount of the insoluble dormant matter into an available form, and are careful not to lose or waste it as it becomes soluble. Much of the skill displayed in good farming consists in well-directed efforts to make the plant food in the soil available, and to secure it in a crop before it is carried away in drainage water.

(1) Change of Dormant into Active Constituents, and Preservation of the Latter.—Several farm operations, which are performed for various purposes, assist more or less in changing the insoluble constituents of the soil into soluble forms which plants can make use of, and in preserving the soluble portions from waste by leaching through the soil. The most important of these operations are the following: *Underdraining,* which admits air into the soil at all times and allows rain-water with carbonic acid in it to pass down through the ground, instead of running off over the surface; *fall-plowing,* which exposes the soil so as to have it thoroughly pulverized by the action of frost; frequent *stirring of soil,* as, for instance, among Indian corn, potatoes, and root-crops, to let plenty of air with its moisture and oxygen down among the constituents of the soil; *thorough tillage,* which not only cleans land but exposes it to the action of the atmosphere; *green manuring,* which consists in growing a crop of some kind for the purpose of collecting plant food and then plowing it under for the use of another crop; and *seeding down* grain-fields with grass and clover, so as to have young growing crops ready to take up and preserve the elements of plant food, especially the very soluble compounds of nitrogen, which become available after harvest and are apt to suffer loss by "washing."

(2) Effects of Rest.—By changes of temperature and the constant action of air and moisture, without any cultivation whatever, the insoluble plant food in the soil is gradually, though slowly, changed into soluble forms, and thus made available for the use of plants. Some of this available food is held by the clay, iron, and humus of the soil; and a portion of it is collected and preserved by grass and weeds, such as grow on nearly all unoccupied land. Thus we see how it is that *rest* gradually restores exhausted or partially exhausted soil to fertility.

(3) Nitrification.—Some of the lower orders of plants, such as smut or rust, feed naturally upon organic matter; but the higher orders of plants cannot do so. The *nitrogen* contained in humus is not in a fit condition to serve as general plant food. Cereals seem unable to use it; and leguminous crops (peas,

beans, clover, and such like) can use it only to a very limited extent, if at all. The humus has to be decomposed by the action of the air or some other agent before crops can make use of the nitrogen contained in it.

All soils contain more or less of a vegetable ferment, which is composed of plants of a very low order—so small that they cannot be seen without the aid of a microscope. These very small invisible plants are generally called *Bacteria* (in the singular, *Bacterium*); and, by their action or growth, they, in some way or other, cause the oxygen of the air to unite with the nitrogen of humus and ammonia so as to form nitrates (compounds of nitric acid with other substances) in the soil. This formation of nitrates in the soil is called *nitrification;* and its importance is due to the fact that nitrates contain nitrogen in a form which is readily available for the use of plants.

In order that nitrification may take place, at least four things are necessary :

(*a*) The soil must be sufficiently porous to let air pass freely down among its particles.

(*b*) The soil should be moist, but not wet. Moisture is necessary; but an excess of water prevents nitrification.

(*c*) There must be a certain amount of warmth. We cannot say exactly how much; but we know that nitrification takes place most rapidly at summer temperatures, and it apparently ceases near the freezing point.

(*d*) The soil must contain lime, potash, soda, or some similar substance, to unite with the nitric acid so as to form nitrates.

These conditions, so far as the farmer can control them, are best secured by underdraining and thorough tillage ; and part of the value of clover and similar crops, which shade and cover the ground during the warm season, is due to the fact that, acting as a mulch, they keep the soil in a moist and porous condition favorable to nitrification.

45. Absorptive and Retentive Powers of Soil.—By
these are meant the powers of soil to absorb moisture, ammonia, etc., from the atmosphere, and to retain water, ammonia, fertilizers, and the soluble portions of plant food in the soil. All

soils have this power to a greater or less degree—vegetable soils in the highest degree, clay soils next, and sandy soils least of all. This important function (or action) of soil is affected both by its composition and its texture. The constituents of soil which have most power to absorb and retain the substances mentioned above are *humus*, *clay*, and *oxide of iron;* and finely divided matter of any kind has much greater absorbtive and retentive powers than coarse materials of the same kind.

Generally speaking, we may say that the power of soil to absorb and retain the invisible watery vapor of the atmosphere and thereby obtain the moisture necessary for the growth of crops in dry, hot weather, is in direct proportion to the fineness of its particles and the amount of humus which it contains: and we may add that the stirring of soil in dry weather, as about young trees and root crops, increases very much its power to absorb moisture from the atmosphere.

46. Loss of Nitrates and Other Substances by Leaching.—Soil, acting as a filter, takes from liquids passing through it most of the substances dissolved in them; but "when water is allowed to drain through soil, it carries with it part of the readily soluble matter which the soil contains."

Phosphoric acid, potash, and ammonia are rarely found in drainage water. The soil holds them so firmly that they are not removed by washing, unless to a very small extent. Nitrates, on the other hand, especially nitrate of lime, and three or four other substances, suffer considerable loss from leaching through the soil. Portions of them are washed down into the subsoil, or carried away in drains, brooks, and rivers.

47. Preservation of Nitrates.—In dry weather the moisture at or near the surface of the soil goes off as invisible vapor into the atmosphere and the water from the subsoil rises by capillary attraction to take its place. Thus the substances contained in the water of the subsoil are brought up again to the surface; and the loss from washing is to some extent prevented.

Now, it has been proved beyond doubt that the evaporation from a growing crop is much greater than from a bare soil; and for that reason *a crop on land*, especially during the warm season

(when nitrification is most active), helps to preserve the nitrates from waste by washing. It does so by increasing the evaporation and thus bringing the water of the subsoil with its nitrates and other soluble substances nearer the surface; and also by taking up part of the nitrates from the soil and changing them into insoluble organic compounds in the growing plants, to be for the most part returned to the soil in the shape of farm-yard manure.

The loss by drainage is not so great in this country as in England and some other places, where their annual rain-fall is much heavier than ours; but even here it is considerable and should be taken into account in all our methods of cultivation and cropping. To prevent it entirely is impossible; but by *growing and plowing under green crops*, in connection with thorough cultivation of the soil, land may be cleaned, enriched, and prepared for wheat, barley, etc., with very little loss of plant food; and the same object may be attained by frequently *seeding down with red clover*. Some recommend very strongly the practice of sowing clover with barley, wheat, and oats nearly every year, in order to have clover sod to plow down as a preparation for all ordinary crops. Under that system the ground is covered throughout the whole growing season—first by a cereal crop and then by the young clover. Thus the nitrates are preserved, weeds are destroyed, and the land is put in first-class condition for the growth of grain, roots, or any other kind of crop.

48. Soil in Relation to Heat.—The warmth of soil has much to do with its fertility. Cold soils cannot be relied on for good crops. From the nature of their substance, some soils are much warmer than others; but the temperature of every soil, whatever its substance may be, is affected more or less by its color, the character of its surface, and the amount of moisture which it contains.

Other things being equal, *dark-colored soils* absorb and radiate (or give out) heat more readily than light-colored soils—they take in more of the sun's rays during the day; and at night they cool down more quickly to the dew-point, that is, to such a degree of coldness in the surface of the soil as causes the air,

coming in contact with the soil, to deposit some of its moisture in the form of dew. *Roughness of surface* in soil is also favorable to the absorption and radiation of heat. But, above all else, the *amount of water* in soil greatly affects its temperature. A soil that is "water-logged" in spring is weeks longer in becoming warm enough for the germination of seed and the growth of crops than the same soil would be if its surplus water were carried off by drains. So we may say that underdraining makes cold soils warmer and earlier; while the application of farm-yard manure and the plowing in of green-crops, such as rye, buckwheat, clover, etc., make light-colored soils darker and thereby increase their warmth.

When perfectly dry, humus absorbs heat faster than clay, and clay more rapidly than sand; but in hot weather sandy soil becomes much warmer than either clay or vegetable mould, because it contains so much less moisture and is a better conductor of heat. Sand also retains its heat much longer than clay or humus.

49. Texture of Soil.—This has reference both to the size of the particles and the condition in which they exist. The mass of the soil may consist of fine, medium-sized, or coarse particles; and these particles may be closely packed together, or baked into lumps, or, on the other hand, they may be well pulverized, and be either finely or coarsely porous.

No matter what the composition of a soil may be, it will not produce good crops, unless it is of a proper mechanical texture. It must be firm enough to give the required support to the crops growing in it, and yet sufficiently loose to allow the delicate root-fibres to extend freely in all directions, according to their habit of growth—fine enough to give capillary power, to hold water, to retain fertilizers, to absorb and retain atmospheric moisture and ammonia, and yet loose and open enough to admit air freely down among its particles and to let the excess of water drain away. In soil of the right texture, water neither lies on the surface nor soaks very quickly through into the subsoil. The excess soon passes away and enough is retained to keep the soil moist and in a fit condition for the growth of crops, except in

very wet or excessively dry weather.   Rain-water is the great carrier, the distributer, and, to some extent, the manufacturer, of plant food ; and unless there is a free passage for it through the soil, the food of plants will not be well prepared, nor will the stationary plant roots be properly fed.   Hence the necessity for draining all water-logged soils.   Nothing else will add so much to their fertility.

Generally speaking, soil should be thoroughly pulverized ; and the finer the particles, the more abundantly will the plant be supplied with the necessary nourishment ; but it is possible to plow and harrow land till it becomes too fine ; and we should remember that different crops, with different habits of growth, require slight differences in the texture of soil.   Barley, for instance, being a shallow-rooted and rapidly-growing crop, requires a very fine, mellow, and comparatively shallow seed-bed ; while that for wheat and oats need not be quite so fine, but it should be worked to a greater depth.   Hence it requires close observation and much skill on the part of the farmer to till his land at such times and in such a way as to have the right texture of soil for each kind of crop.

50. The Best Soil.—The best soil for most purposes is composed of fine sand, clay, and humus, in the proportions necessary to form loam, clay loam, or sandy loam.   Each of these varieties of soil has certain peculiarities of its own : *loam* has perhaps the widest range of uses ; *sandy loam* is a dry, warm, early soil, suitable for barley, potatoes, and various kinds of fruit and vegetables ; *clay loam* is a stronger soil, which contains more plant food, is cooler, more retentive of moisture and manure, and is generally well adapted to the growth of wheat, oats, peas, root-crops, apple trees, etc.   All these varieties of soil are good ; and, when well-manured and properly cultivated, they will grow almost any kind of crop.

51. Correction of Defects in Soil.—Soils containing a large proportion of sand are more or less leachy ; but they can be very much improved by plowing in green-crops and applying farm-yard manure.   Such soils are benefited also by a liberal dressing of either marl or land-plaster.   Heavy clay soil, in its

natural condition, is often wet, cold, and unproductive. Such soil is hard to work and is otherwise unsatisfactory; but its defects can be largely overcome by underdraining, plowing in green-crops or coarse farm-yard manure, thorough cultivation, and an occasional dressing of lime. Soils containing an excess of humus are sometimes sour (from the presence of vegetable acids), and are deficient in available plant food. In such cases, lime may be applied to remove the sourness; and thorough cultivation, by exposing the humus to the air, will decompose some of it and thus make its plant food available. The amount of humus in soil can always be increased by plowing in green-crops or farm-yard manure, and diminished by cultivation and the application of lime.

A soil may contain many of the elements of plant food in abundance and yet be unproductive, owing to an improper mechanical texture, or the lack of some one essential constituent. Such a soil can be made fertile only by proper cultivation and the application of some manure which contains the substance needed. Hence every farmer should be an experimenter on a small scale, trying different kinds of manure on small plots or single ridges, in order to learn what each field needs—we say *each field*, because it would be a mistake for anyone to assume that all his fields require the same treatment.

52. Exhaustion of Soil.—When the farmer grows crops and sells them off his farm, a certain amount of plant food is evidently removed from the land which produced the crops; and a continuance of this practice, without manuring, will sooner or later exhaust the soil of its fertility. Different crops take up the elements of plant food in different proportions—some (mangels, for instance) needing a large amount of potash and only a moderate quantity of phosphoric acid; others, such as wheat, requiring very much less potash with a liberal supply of nitrogen. Plants have also different habits of growth. Some, like peas and barley, are shallow feeders; and others, as wheat and oats, send their roots down to a considerable depth into the soil. Hence land may be exhausted for one crop and still contain plenty of food for another kind of crop—for one of different

habits of growth and requiring the elements of plant food in different proportions. From this it is evident that under a rotation of different kinds of crops, soil will remain fertile much longer than where the same or similar crops are grown in close succession. Nevertheless it is plain that, with the best possible rotation, continued cropping, without liberal manuring, will sooner or later impoverish the soil to such an extent that the crops grown will no longer pay the cost of cultivation; and the only way to avoid this result is either to buy fertilizers, or to keep live stock enough to consume the greater part of the crops (fodder, roots, straw, and grain) produced on the farm, and return it to the land as farm-yard manure—to sell butter, cheese, eggs, and animals, instead of grain.

A poor soil is exhausted sooner than a rich one, a shallow soil sooner than a deep one, and a light soil sooner than a heavy one.

53. Restoration of Fertility.—There is usually a large amount of fertility even in exhausted soils; and rest, as explained in section 44 (2), will gradually make such food available and thereby restore worn-out land to fertility. This, however, is too slow a process: so other means must be used.

We have not space to give in detail the different ways of treating exhausted or partially exhausted land; but the principal operations necessary for restoring fertility are as follows:

(1) *Underdraining*, where necessary, to remove all stagnant water, pulverize the soil, and admit the air down among its constituents.

(2) *Thorough tillage*, to clean the land and expose it to the action of the atmosphere. This may be done by plowing twice after harvest, by summer-fallowing, by the growing and proper cultivation of corn or root-crops, and by various other methods.

(3) *The application of farm-yard manure*, for the purpose of restoring to the land the plant food which is removed in the crops that are grown from year to year.

(4) *Seeding down* with clover or clover and timothy, to clean and enrich the soil, especially to increase the supply of nitrogen in an available form.

(5) *Green-manuring*, or plowing under some kind of green-

crop, to increase the supply of humus and to collect and preserve plant food for the use of succeeding crops. This should be done when there is a scarcity of farm-yard manure. In case, however, the land is too poor to produce a green-crop, it will be necessary to buy either farm-yard manure, or some kind of special fertilizer containing nitrogen, phosphoric acid, and potash,—enough to produce a crop of rye, buckwheat, or something else to plow under.

(6) *Keeping the ground covered with a crop* as far as possible during the growing season, to prevent waste of plant food, especially nitrates, by leaching through the soil.

To explain more fully the method of cleaning and enriching soil by means of green-manuring, or by green-manuring and seeding down, we may give an example or two: (1) Plow the ground early in the fall and sow a crop of rye. In the following spring, when the rye is well grown, plow it under, and sow at once a crop of buckwheat (about two bushels per acre), or some other quickly-growing crop suitable to the locality. When the buckwheat or other crop is in full bloom, plow it down. Then harrow and roll the ground, and let it stand till the crop plowed under is pretty well rotted; after which plow again in fall or spring as a preparation for seed. (2) Another and probably better method is to plow the ground in the fall; and in the following spring grow and plow under two crops of buckwheat in succession (using, say, two bushels per acre of seed for each crop), one immediately after the other. Then work as the condition of the soil may suggest, sow some cereal crop and seed down with clover. After taking a crop of hay, or one of hay and (where possible) one of seed in the same season, plow the clover sod, work it for another crop, and seed down again with clover and timothy.

Other methods of restoring fertility may serve the purpose equally well, or better; but, in case manure is not purchased, one thing is always necessary, viz., to keep live stock enough to consume on the farm the whole or nearly the whole of the coarse grains (peas, oats, corn, etc.), as well as the straw and root-crops, grown from year to year, in order to have plenty of

farm-yard manure, which should be regularly and systematically applied to the land.

Methods for restoring the fertility of the soil will be treated more at length in subsequent chapters.

CHAPTER IV.

Tillage: Introductory.

54. Definition of Tillage.—By *tillage* is meant the various processes required for the proper cultivation of the soil. It includes the improvement of the soil, the preparation of the soil for the seed, the rotation of crops that should be adopted, the growth and management of crops, including soiling crops, and the methods employed for the destruction of weeds.

55. Tillage Often Defective.—On too many of our Ontario farms tillage is very defective, and in no country of the world does it receive the attention it should receive. As illustrations of defective or improper tillage, there may be mentioned the too common practice of imperfectly preparing the soil for the seed; the too little attention that is usually given to the maintenance of the fertility of the soil or to means for improving it; the too little attention that is usually given to drainage; the too prevalent practice of sowing seed having the seeds of weeds mixed with it; and the still more prevalent practice of allowing weeds in myriads to grow and ripen almost everywhere.

56. Advantages of Proper Tillage.—The adoption of improved modes of tillage increases very much the yield of crops without adding proportionately to the cost of producing them. The difference between the expense of producing a crop (including as part of the expense the rent of the land occupied) and the sum obtained for the crop when it is produced, is the profit. The cost of the labor is usually the largest item of expense in the production of a crop; but the labor of caring for

a good crop is not much more than that which is required to care for a poor one, while the difference between the respective returns may be large. And often it is wise to add to the cost of production in other things besides in labor. Ten dollars of extra expense applied to an acre of land in manuring it properly may increase the value of the wheat grown on it by fifteen dollars, while the cost of caring for the crop will not be equally increased ; moreover, the land itself will be left in better condition for the next crop than if it had not thus been manured. So that, speaking generally, it follows that the larger the yield obtained from crops, the greater in proportion are the profits in growing them likely to be. It is the opinion of competent judges that the average yield of the crops of Ontario would be increased at least by *one-third* if only proper methods of tillage were generally adopted.

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CHAPTER V.

Tillage : The Improvement of Soils.

57. The Processes Concerned in the Improvement of Soils.—The improvement of soils depends more or less directly upon all the processes of cultivation. But in a more restricted sense the processes concerned in the improvement of soils comprise (1) drainage; (2) the application of manures; and (3) certain other processes somewhat akin to manuring, such as trenching, subsoiling, and irrigation.

DRAINAGE.

58. What is Meant by Drainage.—By *drainage* is meant the removal of superfluous water from the soil. It is of two kinds, viz., surface drainage and underdrainage.

59. Surface Drainage.—*Surface drainage* means the removal of water from the surface of the soil by the use of open

channel of greater or less depth. Ordinarily these channels consist of the furrows left by the plow between the ridges, and of other furrows made to cross these and follow the natural descent of the low parts.

Where land with a very close or impervious subsoil is not underdrained, careful attention should be given (especially in autumn) to the size and shaping of the ridges made by plowing, and also to the cleaning out of loose soil from the cross furrows referred to above. The more impervious the subsoil, the narrower and more rounding should the ridges be made.

Where water runs the whole year through, as, for example, in a rill from a spring, it is well to keep a narrow ridge of grass on the borders of the rill, lest earth be drawn into it in the processes of cultivation. In those depressions which, though dry in summer, carry large quantities of water during certain seasons of the year, the ditches should generally be made with a scraper, and the edges should be gently sloped, that cultivation may be easier.

Surface ditches, when in flow, carry away valuable soil ingredients, and for this reason are objectionable; but in wet soils, not provided with underdrainage, they cannot be dispensed with.

60. Underdrainage.—In the state of nature, lands for the most part sufficiently drain themselves by means of hidden channels of percolation that perhaps have existed for ages; but in cultivation these passages are closed up, as, for example, by the treading of horse-hoofs and otherwise. Hence arises the necessity for opening artificial passages, that is, underdrains.

61. Three Kinds of Surface Water.—Surface waters, with respect to their origin, may be spoken of as being of three kinds, viz., ooze water, spring water, and rain water. *Ooze water* is that which has soaked out from adjoining land. As it has left most of its nutriment in the soil through which it has passed, it is of no use to vegetation; in fact, it is injurious to it. *Spring water* is that which is conveyed to the surface in more or less steady flow through passages more deeply buried. It is as hurtful to vegetation as ooze water. *Rain water* is that which

has descended directly from the clouds. As it always contains plant food dissolved in it (see section 30), it is beneficial to the soil, and it is the farmer's duty to utilize this beneficial quality as much as may be. When made to pass through from two to four feet of surface soil, its fertilizing ingredients are retained by the soil; but if it be allowed to run away over the surface, these fertilizing ingredients are lost to the soil, and, in addition, much nutriment is washed out of the soil along with it.

62. Indications of a Want of Drainage.—*Surface indications* of a want of drainage are (1) standing water; (2) prolonged dampness in plowed land; and (3) cracks in the soil in dry weather. *Vegetative indications* are (1) a curling o corn in the leaf; (2) a wiry appearance in the growth of grass; (3) the formation of a mossy substance on the surface of the ground; and (4) a spindling growth in grain crops, with a lightness of tinge in their color. To which it may be added, that should water collect during the wet weather of spring, in a hole dug in the ground to the depth of, say, four feet, it would be a sure indication that the land required underdraining.

63. Benefits Derived from Underdraining.—When underdraining is properly done, the following are among the benefits which it secures: ·   ▲

(1) It promotes filtration, and so renders the soil more porous; and hence, too, it facilitates deep and thorough cultivation. When land is well drained, and the surface water is rapidly carried off by filtration, it quickly dries, and in drying contracts. When it becomes wet again, it expands; and the alternate contraction and expansion so caused separates the particles of the soil from one another, and thereby makes it loose, friable, and more easily worked.

(2) It "warms" soils by lessening evaporation. When land is well underdrained most of its surface water is carried off in the drains, and as a consequence the amount that is left to be carried off by evaporation is greatly lessened. Hence, as evaporation is always accompanied by a lowering of temperature, the soil of well-drained land will not be so much cooled in consequence of evaporation as the soil of undrained land. The importance of

underdraining in its effect on the temperature of soil will be recognized when it is stated that there is sometimes a difference in temperature between lands drained and undrained, though lying side by side, equal to that which would be caused by a difference of 2000 feet in altitude.

(3) It prevents the "baking" of the surface of the soil. It does this by carrying off the surface water by *filtration*. If the surface water is carried off by *evaporation mainly*, the fine mud occasioned by the standing water becomes hardened as it dries, and breaks into cracks. Underdraining, by promoting filtration, prevents this.

(4) It promotes plant growth (*a*) by permitting the air to enter into the soil through the little passages the water has made for itself in its descent to the underdrains, and thus enabling the soil readily to extract from the air nutriment necessary to plant growth in the form of carbonic acid gas, ammonia, and nitric acid (see section 8); (*b*) by lowering the water-table or line of saturation, and thereby deepening the foraging ground of plant rootlets; (*c*) by enabling vegetation better to withstand drought; (*d*) by promoting the fermentation of manures; and (*e*) by preventing the "heaving" of plants through the action of frosts.

(5) By the quick removal of superfluous moisture, it lengthens the season for cultivation and thereby greatly facilitates the labor of tillage.

(6) And because of these advantages it enables the farmer to obtain much better returns for his outlay. Those farmers in this country who have underdrained their lands have found that the entire cost of doing so has been in from two to eight years wholly repaid to them by the increase obtained from their crops.

64. Materials Used in Underdraining.—The materials used in underdraining are sods, brush, wood, stones, and tiles. The use of sods and brush is now given up almost everywhere. Stones are not so much in favor as they once were, and wood is used only in new countries. For cheapness, efficiency, and durability, underdrains made with tiles are far the best.

65. Tiles.—Tiles are made of burnt clay. Of the several kinds in use the round ones are the best, since in laying them they can be so turned as to make close joints; and, moreover, they can be

used with collars. A *collar* is a short tile, large enough to surround the joint where two tiles meet. It is used to keep out silt,* but its use in this country has not become at all general.

Tiles are usually about 13 inches long, but those of greater length are now beginning to be used. In ordinary drains tiles from two to three inches in diameter are employed; but in some drains they are used even as large as six inches in diameter. In constructing a drain, all tiles should be rejected that will not ring clearly when struck with a piece of steel.

66. Systems of Drains.—All the various drains used in removing the water from a piece of land, for which there is but one outlet, or final place of discharge, for the water, are spoken of as constituting "a system of drains." These may comprise main drains, submains, and laterals.

The *main drains* lead up the lower parts of the valley, and receive the water from the submains and laterals. In any drain, and especially in a main drain, the utmost pains should be taken to have the bottom, or floor, of uniform grade or inclination. This is necessary in order to produce an unchecked flow of the drainage-water and so prevent the collection of silt. When the size of the bore of the tile is to be reduced in the ascent, it should be done by using a decreasing tile (as shown in Figure 7).

Fig. 7.

The *submains* should ascend the smaller valleys. Where these valleys are wide there may be two submains, one skirting the base of each of the bordering slopes.

The *laterals* are the smaller drains. They should, so far as practicable, be joined with the submains or with the main drains, at acute angles (as shown in Figure 8), in order to facilitate the egress of the water. When one drain approaches another at right angles,
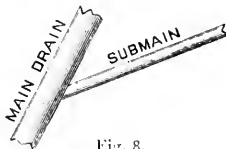
Fig. 8.

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*Silt is the mud or fine earth which is deposited from water that holds soil in solution. The deposit usually takes place where the water is more or less impeded in its flow. Hence, in drains, wherever the drainage-water is checked, or brought to a standstill, silt accumulates, and the accumulation is likely to go on until the drain is choked.

the joining must nevertheless be made at an acute angle. This

Fig. 9.

is effected by the use of a curved tile (as shown in Figure 9). Drains should never be carried squarely across the side of a hill, for in that case the drain will draw water only from the upper side; but wherever practicable they should ascend the hill in the most direct route possible.
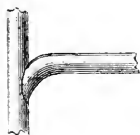
67. The Depth of Drains and their Distances Apart.

—The *depth* of drains depends upon the character of the soil to be drained, and the nature of the crops that are grown upon it. In this Province they are generally sunk to the depth of three feet, or a little less than this. The deeper the drain, the greater will be the area which it will drain, and the lower also will it reduce the level of the undrained water, or, as is said, the lower will it make the "water-table." Drains should be deep enough to escape the action of frost.

As to the *distance apart* at which drains should be sunk, there is no fixed rule. This distance will depend upon their depth, and upon the "stiffness" or "openness" of the soil to be drained. For four feet drains, the usual distance is about 40 feet, and for three feet drains, about 20 feet.

68. Silt Basins.

—The silt of drain water, that is, the soil held in solution by it, is sure to be deposited in places where the water is slack. Slack water occurs where there is a break in the descent or grade of a drain. Sometimes the slack is made to

Fig. 10. Silt Basin.

occur intentionally, as in basins beneath the drain called *silt basins*. A silt basin may sometimes be simply a single tile set on end beneath the juncture of two other tiles (as in Figure 10). Into it the water flows, deposits

sediment, and then flows on. This sort of silt basin used to be quite commonly employed to hold the silt that occurred where one drain joined with another; but its necessity is now done away with by the use of the "junction-tile" (see next section).

For large drains, or where the waters of several drains are

collected, the silt basin may consist of a chamber built of stones or bricks, and covered with a flat stone. The place should be carefully marked, so that the basin may be examined at intervals and cleaned out.

69. Junction Tiles.—The introduction of the use of junction tiles (Figure 11) has, as was said in the last section, largely done away with the use of silt basins. The reason of this is that, formerly, when a lateral drain connected with a main, the junction

Fig. 11. Junction Tile

was made so that the water *fell* from the lateral into the main. By reason of the sudden checking of the flow of the water which this fall occasioned, silt was deposited where the fall took place. Now, by the use of the junction tile, there is not so great a check to the flow of the water: hence but very little silt is deposited, and so the silt basin is frequently not at all necessary.

70. Draining Tools.—The principal tools used in draining are—the ordinary spade and shovel; the ditching-spade (Fig.
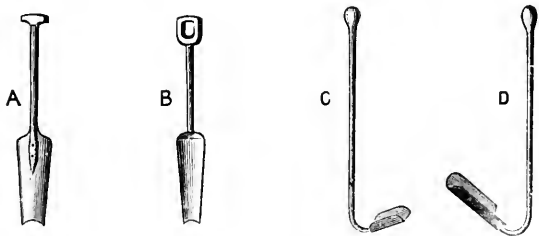
Fig. 12. Draining Tools.

12, *a*); a second ditching-spade (*b*), longer and narrower than (*a*); the "scoop" (*c*), with a bill four inches wide; the "snipe-bill scoop" (*d*), with a bill but three inches wide at the point; and a pick.

71. Construction of Drains.—In draining a piece of land, the first thing to be done is to ascertain if there is a sufficient fall in the ground; that is, if the outlet of the main drain can be made low enough to carry away the water from the drains above. This is ascertained by using levels of various kinds. The

ordinary level and "straight-edge" will suffice. The ground
should then be carefully examined for the courses which the drains
should take, accurate measurements being made; and then
stakes should be set where the drains are to be dug. By
carefully laying out a system of drains, a saving of one-fourth in
the length of the drains is sometimes effected. When the
system is fully planned, a map of it should be carefully drawn,
and this should be preserved for reference when repairs are to be
made.

72. The Outlet.—The outlet of a drain or of a system of
drains (Figure 13) should be placed at the lowest possible
position. In constructing it, a strong floor of stone or of planks
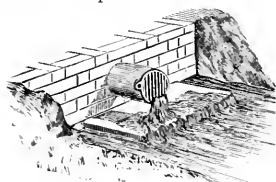should be placed below. A broad plank, or (which is better) a

flag-stone, should extend some
distance forward to receive the
flow, and backward to prevent
undermining. Stones or bricks
may then be built in around the
tile, and these may extend a
short distance both backward, up

Fig. 13. Outlet of a Drain.   the drain, and forward, beyond

the end of the tile. If the end-tile is of glazed or vitrified ware,
it will better withstand the action of frost. The number of
outlets should be as few as possible, because of the cost of
constructing them and keeping them in repair. The fewer open
ditches there are, the fewer outlets will there be.

73. Cutting a Drain.—In cutting a drain the first thing to
do is to draw along its course two or three furrows with the
plow. Then the earth is to be lifted out with a shovel. This
being done, a subsoil plow is then sometimes used, which should
be drawn by a strong horse walking in the furrow. The
remaining portion of the depth must be dug by hand. In cutting
the drain, care should be taken that it be kept as narrow as
possible, in order to avoid all unnecessary handling of earth.
Where there is but little fall, and in wet soils, the entire length
of the drain should be cut before the tiles are laid, as in this way
the deposit from muddy water is kept out of the tiles.

74. Grading the Bottom of the Drain Uniformly.
—This is of the utmost importance, for if the bottom of the
drain is not even and uniform, the flow will be hindered and silt
will be deposited.   Various methods are adopted to guide the
digger in effecting this ; but the simplest one is to pour in water
and observe the places where the water slackens, and then make
the necessary corrections.   Some object to this practice because
it tends to soften the bed which is to receive the tiles.

75. Placing the Tiles.—In placing the tiles, the operator
usually stands in the drain, laying the tiles in front of him, and
making close joints by the aid of the tile pick.

76. Refilling the Trench.—In refilling the trench, the
firmest of the earth and what is free from stones should be put
in first and well tramped down to the depth of 15 to 18 inches.
After this the plow or some sort of scraper may be used.

77. Draining a Spring.—When a spring is to be drained,
the water should be caused to run into a pit having a large tile
sunk endwise in the centre.   This tile should then be tapped by
a line of tiles running directly to a submain or to a main drain.
Sometimes, however, more than one pit is necessary.

78. Draining Springy Lands and Marshes.—In
draining *springy soils* that are always wet, it is best to dig only a
portion of the depth at one time, to repeat the process at
intervals, and to complete the work in the dry weather of
autumn.

In draining *marshes* which contain much water, it is frequently
necessary to cut large open ditches, and drain into these.

79. Draining in Quicksand Subsoils.—In draining
land that has a quicksand subsoil, the drains must be sunk
deeper than the depth intended for the tiles, and boards should
be placed on the bottom to serve as a bed for the tiles.   Hard clay,
however, will be found to be even better than boards.   Clay,
also, should be packed around the tiles to keep out silt.

80. Ditching Machines.—Various kinds of ditching
machines are now in use for the purpose of cutting drains more
quickly than they can be cut by manual labor.   Some of these
are drawn by horses, and others are propelled by steam.   They

have been found quite useful in land which is free from stones, but in stony land they cannot be profitably used.

MANURES AND THEIR APPLICATION.

81. What Manures Are.—Manures are substances which are applied to the soil to furnish it with materials for plant growth, when these are not already present in sufficient quantities.

82. The Cause of Poverty in Soils.—A deficiency in the soil of material suitable to plant growth may arise from the exhaustion caused by continued cropping, as well as from original poverty of composition. The continued removal of crops from a farm, or of bones, flesh, milk, and wool, produced from these crops, without returning to the soil a suitable equivalent, produces an impoverished condition of the soil, which, in the end, renders unprofitable the labor of cultivating it.

83. The Plant Food of the Soil.—Plants absorb from the soil a large number of substances which may very fittingly be called their food (see section 19). But, in practice, nitrogen, phosphoric acid, and potash, are alone to be considered, because the other elements of plant food are usually present in the soil in quantity sufficient to sustain vigorous plant growth; and because also nearly all manures that contain these three elements contain those other elements as well.

It would require many years of continued cropping to exhaust a soil of *all* its nitrogen, phosphoric acid, and potash; but that which is *available* of these plant food ingredients (see section 44) may be exhausted in a few years. To produce a full crop, the soil should contain much more of these substances in an available form than what is necessary for the growth of the crop; for no plant is able to gather more than a small portion of the available plant food contained in the soil in which it grows, while that which is not available is quite useless to it.

84. Classification of Manures.—Of manures that are used in practical farming, farm-yard manure and commercial fertilizers are the two principal classes; but, in addition to these, composts and green-manures are extensively used. Manures are also classified as being general and special.

Farm-yard manure consists of the excrement (both liquid and solid) of the animals that are fed upon the farm, and of the litter that has been used as bedding which is mixed up with this excrement.

Commercial or *artificial fertilizers* are composed of various fertilizing ingredients obtained from natural products, but prepared by special processes of manufacture, sometimes mechanical, sometimes chemical, sometimes both mechanical and chemical. These manures, in order to save the cost of carriage, are usually sold in a concentrated form.

Composts are manures obtained by the admixture and fermentation of suitable materials obtained on the farm, usually swamp-muck, leaves, and ashes, and sometimes bones.

Green-manures are the manures resulting when growing crops are plowed under for the purpose of fertilizing the soil.

A *general manure* is one which contains all the essential elements of plant food.

A *special manure* is one that is used when soils are deficient in some of the elements of plant growth, or one used to supply the excessive demand for some one element of plant food.

85. Use of Manures.—The principal use of manures is to supply the soil with plant food ; but they have other uses. Some manures, as lime, for example, act upon both the organic and inorganic constituents of the soil and hasten their decomposition. Some, as nitrate of soda, when dissolved by water, have a powerfully solvent action on the mineral matters of the soil. Others, as farm-yard manure, improve the soil mechanically.

86. The Application of Manures.—At first sight it would seem a safe rule to follow, in manuring a soil, that such manures should be applied as contained the elements of plant food needed by the crop intended to be grown on the soil. But this is not a safe rule to follow, for some soils naturally will contain some of these elements in far larger proportion than other soils, and therefore will not require that these elements shall be added to them. Plants also differ in their capacity for supplying themselves with food present in the soil. Although clover needs more nitrogen than wheat, it obtains its

supplies with less difficulty, owing to its habit of deep growth and to the construction of its roots. In applying manures, therefore, we should take into account, not only the needs of the crop, but also the ability of the soil to supply these needs, and the ability of the crop to take advantage of the food which the soil contains, and also the mechanical condition of the soil. More will be said about the application of manures under the various crops of the farm.

87. Farm-yard Manure.—It is upon farm-yard manure that the farmer must principally rely for maintaining and restoring the fertility of his soil. Farm-yard manure contains all the most valuable elements of plant food. No other manure benefits a soil so much, both chemically and mechanically, nor can any other be applied to all sorts of lands with such positive certainty of beneficial action. Moreover, it is peculiarly durable in its effects.

88. Its Quality.—The quality of farm-yard manure depends upon the kind, age, and condition of the animal producing it; upon the food and accommodation given to the animal, and the amount and quality of the litter supplied to it; also upon the treatment bestowed upon the manure during its accumulation, and upon its after treatment.

89. Differences in Farm-yard Manures.—Manure obtained from matured animals is more valuable than that produced by young and growing stock. In all animals the phosphates of their food are used in the production of bone, while other salts and the nitrogen of their food go to make muscle, flesh, and fat. Hence in young and growing animals, since their bones and muscles are continually becoming larger, a greater use is necessarily made of these food constituents than in mature animals, whose food is needed only to supply waste and not to build up bone and muscle; and hence also these constituents are more or less wanting in their excrement. So it follows that the manure which this excrement is made into lacks in phosphates and nitrogen. In a similar way, it may be shown that the manure obtained from lean animals is less valuable than that produced by animals already fully developed and not needing to form new flesh.

Similarly, the manure obtained from "beef-making stock" is more valuable than that produced by "milk-producing stock." The plant food in the manure must all come from the food eaten by the animal making it.   Also, the plant food contained in the food eaten by the animal will all be found in its excrement, except what has been retained for the production of blood, bone, muscle, fat, etc., and of milk.   Now, in milk-producing stock from 25 to 50 per cent. of the nitrogen, phosphoric acid, and potash contained in their food is taken up in the production of the milk yielded by them, while a much less quantity of these constituents would be retained in the animal were it fed for fattening or to produce beef.   It is therefore apparent that the manure produced by beef-making animals will be much richer in phosphoric acid, nitrogen, and potash (which, as has been said before, are the most valuable constituents of manure) than that produced by milk-producing animals.   The manure made by "beefing" animals is also still more valuable on account of the rich nature of the food given to animals when fed for the purpose of producing beef.

90. Importance of Good Floors in Stalls and Manure-Yards. —When manure is collected from stables in which the animals are tied in stalls, unless the floors are well made (as, for example, with some kind of concrete) much of the liquid portion of the manure will be lost.   This liquid portion is the most valuable part of farm-yard manure, for the reason that the elements of plant food contained in it are in a soluble condition, and thus readily available to support plant growth.

91. Importance of Litter. —When manure is made in box-stalls or in covered yards, it is usually of a good quality, because the solid and liquid portions of the manure are well intermixed with litter, the litter preventing the liquid portion from being lost.   Manure made in open yards is liable to be injured by the leaching effects of rain, unless the buildings adjoining have eave-troughs, and the bottom of the yard be concave and retentive.

92. Quantity of Litter to be Used. —While there should always be sufficient litter to absorb all the liquid manure produced, more than this is injurious, since it tends to retard fermentation.

93. Quantity of Moisture in the Manure Heap.—It is important that the fermentation of manure take place under proper conditions. When fresh manure is allowed to remain in a heap it soon becomes hot, and if it be not kept moist there is a serious loss of nitrogen in the form of carbonate of ammonia, which is ammonia in an exceedingly volatile form. The escape of ammonia is indicated by its strong odor; but it may be arrested, or, what is better, prevented, by keeping the heap moist, and scattering some land-plaster over it.

94. Necessity of a Covering for the Manure Heap.—*Leaching*, or the washing out of the soluble parts of the manure heap by rain or other water, seriously impairs its value, sometimes to the extent of at least 50 per cent. Keeping the heap under cover prevents this. But the greater loss of nitrogen from "fire-fang," or "dry mould," caused by over-fermentation (as described in the preceding section), must also be avoided. Mixing manures from different kinds of stock tends to prevent this loss.

95. Application of Farm-yard Manure.—To draw manure to the field and plow it under as soon as possible after it is made, is a safe rule to adopt.

The labor employed in the work of spreading the manure is an important item in the cost of manuring. Hence, if the spreading can be done in winter, when labor is comparatively cheap, there is an obvious advantage. On land that is not hilly the spreading may be done in winter, the manure being taken from the yard as soon as it is made; but in that case, as there has been no fermentation, the weed seeds that it contains are likely to grow.

More will be said concerning the application of farm-yard manure under the heads of the various farm crops.

96. Commercial or Artificial Fertilizers.—Besides the manure that is produced in the farm-yard, there are numerous other manures produced from various natural products by means more or less artificial and intricate. These may be called commercial or artificial fertilizers. They are obtained from animals, vegetables, and minerals.

97. Animal Artificial Fertilizers.—Of the artificial fertilizers obtained from *animal* products, guano, blood, bones, the refuse flesh of animals killed for food, and fish refuse, are among the chief.

Guano is the accumulated excrement of the myriads of sea-birds that for long ages have frequented certain sea-coasts and sea-islands, especially on the south-western coasts of South America. The best guano has been found off the coast of Peru, one reason being that that region is destitute of rain, and hence the guano found there has not been exposed to the leaching effects which rain produces. The supply of natural guano is now pretty well exhausted.

The chief ingredients of value in guano are ammonia and ammonia-forming compounds, and certain phosphates. The quantity of the best guano to apply to an acre is from 200 to 500 lbs. Its stimulating effects as a top-dressing are very marked.

Blood is largely used as a manure, but chiefly with other fertilizers. Mixed with bone-dust or phosphatic guano it forms an excellent fertilizer for turnips. It contains a large amount of nitrogen.

Bone is made up of two sorts of substances, viz., mineral or earthy matter, and animal matter. The earthy matter comprises about two-thirds of the whole, and consists principally of phosphate of lime ; and it is to this constituent in their composition that bones mainly owe their value as a fertilizer, since it furnishes phosphoric acid, a very necessary element of plant food. But the animal matter of bones is also valuable as a fertilizer, since it furnishes the soil with nitrogen, another very necessary element of plant food.

Bones are most commonly used for manures in the form of bone-dust, bone ash, and bone super-phosphate of lime.

Bone-dust or *bone-meal* is obtained by crushing or grinding bones to a kind of coarse powder. The finer the meal the more rapid is its action as a manure. The application of bone-meal to light lands or to old pastures gives most marked results.

Bone-ash is what is left after bones are burnt, which process deprives them of their animal matter, and, therefore, of their

nitrogen. It is chiefly used in the manufacture of the super-phosphate of lime.

Bone super-phosphate of lime (generally called "bone super-phosphate") is formed by treating bone-dust (or bone-dust and bone-ash together, or bone-ash alone) with sulphuric acid. It is applied at the rate of from 200 to 500 ℔s. per acre.

Fish refuse is often used as a manure, generally in a prepared state; but sometimes it is applied directly to the land. *Fish guano* is a fertilizer manufactured from the refuse of oil-pressing and fish-curing establishments by treating it when under pressure with sulphuric acid. It does well as a manure for wheat and some other crops.

98. Vegetable Artificial Fertilizers.—The leading artificial fertilizer obtained from a *vegetable* source is wood ashes.

Wood ashes are rich in potash, and it is for this reason that they are so valuable as a manure. They will benefit almost any kind of soils that are dry. They are very useful to clays, since they render them less stiff and more workable; but they are especially useful to light soils, since they furnish these soils with the potash in which they are naturally deficient. Their effects are most marked on grass lands, and on wheat, potatoes, turnips, and fruit trees. When unleached, they may be applied at the rate of 100 to 200 bushels per acre, if placed on or near the surface; and when leached, in much larger quantities.

99. Mineral Artificial Fertilizers.— Of the *mineral* artificial fertilizers, lime, gypsum, marl, salt, and the various phosphates, are the chief; but besides these, there are also several mineral fertilizers which are valuable for the *nitrogen* which they afford, two of which will be described in section 100.

Lime exerts a four-fold influence as a fertilizer:

(1) It is a direct source of plant food; that is, it supplies the growing plant with an element it needs, namely, the chemical substance called calcium (see section 17 (2)).

(2) It acts upon the organic matter of the soil (that is, the decayed vegetable matter), neutralizing the "sour" organic acids that it contains, and rendering the soil "sweet" and capable of sustaining healthy plant life.

(3) It unlocks the stores of inert mineral matter in the soil, especially the potash and soda (see sections 35, 38, and 44), and renders them available as plant food.

(4) It ameliorates the texture of soils that are too stiff; that is, makes them more easy to be plowed, harrowed, rolled, etc.

Lime improves the quality of grain, grasses, and other crops; hastens their maturity, destroys insects, and checks the growth of moss. While it improves the texture of strong clays, it also increases the capacity of light soils for absorbing and holding moisture (see section 39).

The amount of lime used may vary from one ton per acre to ten tons. One to two tons is an average dressing. A deep soil requires a heavier dressing than a shallow one, and a sandy soil less than a heavy clay. Soils rich in organic matter (that is, decayed vegetable matter) require more than soils poor in the same. A small amount will benefit drained lands more than a large amount will benefit those that are undrained. Small dressings and frequent are preferable to larger ones infrequently applied. The lime intended as manure should be harrowed in rather than plowed in.

Lime is used both in its natural condition and after being burnt. *Burnt lime*, or *"quicklime,"* as it is called, is much more active in effecting the changes described in (2) and (3) above than *natural lime*, and, indeed, is the form in which lime is generally used in agriculture. But since on some soils quick-lime will do much more harm than good, it should always be used with judgment and caution. (See also section 39.)

Gypsum (sulphate of lime) is largely used as a fertilizer, especially for clover, grasses, turnips, potatoes, peas, and corn. Its value as a fertilizer is largely due to its action in fixing carbonate of ammonia (which is, as was said in section 93, an exceedingly volatile substance) and conveying it to the roots of plants. It should be sown on young crops when they are well above the ground and are moist with rain or dew. The proper quantity per acre for clover and peas is about 100 lbs. On corn and turnips it is sufficient simply to dust it along the rows.

Marl, which is a natural mixture of clay and carbonate of lime,

is abundant in some parts of this Province. It varies much in color, being blue, grey, red, and yellow. The blue and yellow kinds are the most valuable. Marl will be found useful on all soils on which lime may be beneficially used.

Salt is now extensively used as a manure. It tends to stiffen and brighten the straw of cereals, and to destroy insect life. Its effects are most beneficial in the growth of wheat and mangels. When sown upon wheat, its effects are improved by mixing nitrate of soda with it. When used upon ground intended for roots, it should be sown just before the drills are made. It may be applied at the rate of from 200 to 500 ℔s. per acre.

"*Phosphates*" is a general term applied to several compounds, all of which are sources of phosphoric acid, and therefore (see section 40) all helpful in sustaining healthy animal life: as, for example, the phosphate of lime, the phosphate of soda, the phosphate of potash, and the phosphate of magnesia. But by far the most important of these, from a farmer's point of view, is the phosphate of lime, and therefore when the word "phosphate" is used without any qualification, phosphate of lime is generally understood.

Phosphate of lime is found in great abundance in the bones of animals, as has been said (see section 97); but it is also the chief constituent of some widely distributed minerals, as, for example, *apatite*, *phosphorite*, and *coprolites*. It occurs in small quantities in all fertile soils. Next to potash and the nitrogenous elements of the soil, it is the plant food most largely drawn upon in the growth of cereals.

In Canada, the word "phosphate," when spoken with reference to farm operations, generally means the mineral *apatite*, for this mineral is popularly called by that name. The value of apatite as a fertilizer is due to the phosphate of lime of which the mineral is principally composed. Our Canadian "phosphate" (that is, apatite) does not dissolve easily in water. Hence, to make it efficacious as a manure, it must be ground to a very fine powder before being applied to the soil, since in a powdered state it dissolves much more readily.

Mineral "superphosphate" (that is, *superphosphate of lime*) is

produced by treating apatite, coprolites, or other mineral phosphates, and bone-ash, with sulphuric acid. The real value of mineral superphosphate is much the same as that of bone superphosphate, but the price of the former is often much higher.

100. Nitrogenous Fertilizers.—The two principal nitrogenous fertilizers are nitrate of soda and sulphate of ammonia.

Nitrate of soda is a natural product and is found very abundantly in Chili and Peru, whence it is known as Chili saltpetre or Peruvian saltpetre.

Sulphate of ammonia is wholly an artificial manure, and is produced by treating ammonia with sulphuric acid.

Both these manures owe their value as fertilizers to the nitrogen which they contain (see sections 36 and 40). They are found especially useful when applied as a dressing to cereals and root crops after spring growth has commenced. The quantities to be applied per acre are about 150 ℔s. of the nitrate of soda, and 100 ℔s. of the sulphate of ammonia.

101. Application of Commercial or Artificial Fertilizers.—Regarding the application of artificial fertilizers, the following observations are of value:

(1) In using fertilizers of a soluble character (as, for example, guano, blood, fine bone-dust, bone superphosphate), the aim should be to manure the plant rather than the soil. They should therefore be applied on the surface or drilled in with the seed.

(2) Fertilizers not readily soluble (as mineral phosphates, marl, lime, etc.) produce the best results when mixed with the soil, the reason for this being that *time* is required in order that the plant-food ingredients contained in these fertilizers may be changed from an unavailable or dormant condition to an available condition (see section 44).

(3) Slow-acting fertilizers may be buried more deeply than others, but none should be buried too deeply.

(4) Top-dressing with artificial fertilizers is to be recommended chiefly for crops in the grassy stages of their growth.

More will be said concerning the application of artificial fertilizers under the heads of the various farm crops.

102. Composts.—The chief substances used in making

composts on the farm are pea , swamp-muck, road-scrapings, garden refuse, cleanings of ditches, weeds, leaves, and lime. The chemical changes which these substances undergo under fermentation in the compost heap render them valuable as manures. The attention given to compost heaps is less now than it was before the introduction of artificial fertilizers, for the reason that the latter are often cheaper and require less labor in their application.

103. Green-Manures.—The plowing-in of green-crops is one of the most effective methods of enriching the surface soil. Green-crops necessarily contain elements of fertility derived from the air and from the mineral and vegetable constituents of the subsoil on which they grow, as well as those they have taken from the surface soil. Therefore, when green-crops are returned to the earth and left to decompose in it, as by the process of "plowing-in," they naturally not only restore to the surface soil those elements of plant food which they have taken from it, but also add to it those elements of plant food which they have derived from the air and from the subsoil. The plants therefore best adapted for use as green-manures are those that derive their support largely from the air and from the subsoil ; that is, those which grow rapidly and cover the ground well, and whose roots penetrate deeply. The growth of these crops may with advantage be largely increased by the use of artificial manures.

Buckwheat, rye, rape, clover, and corn, are chief among the green crops used as green-manures in this country ; and of these clover is the most valuable, owing to its habits of deep growth. These green-manure crops are used most profitably in conjunction with a summer-fallow, and they should be plowed in as near as possible to the time of flowering. The improvement which they effect in the texture and fertility of the soil is most marked in clays The use of green-manure crops furnishes a cheap and efficacious method of manuring for lands remote from the buildings of the farm.

TRENCHING.

104. What Trenching is.—Trenching is a process by which subsoils are brought to the surface and intermixed with

the surface soils.   The only form in which trenching is practised in this country is that of *trench-plowing*, which is but another name for deep plowing.

105. Why Trenching is Beneficial.—Trenching is beneficial because it *deepens* the *surface soil;* that is, it brings up to the surface a portion of the subsoil containing unused plant-food ingredients ; and though these may be in an unavailable condition, yet through atmospheric agency they in time become available, and so add to the fertility of the soil

106. When · Trenching is Beneficial.—Trenching is beneficial

(1) When the lands are of the same nature below as on the surface.

(2) When the upper layer is clayey or compact and rests upon a bed of limestone or sand.   In this case the texture of the clayey surface soil will be ameliorated.

(3) Whenever the lower soil contains elements of plant food that would be more valuable upon the surface.

When the subsoil is inferior the deepening process must always be a gradual one, if it is to be beneficial.

SUBSOILING.

107. What Subsoiling is.—In subsoiling, or subsoil-plowing, the land lying immediately beneath the surface soil is stirred and opened, but not inverted or brought to the top.   The process is effected by a plow made for the purpose.   Usually, a common plow goes before, throwing out a large furrow-slice; then the subsoil-plow follows, stirring the soil beneath to the desired depth.   This depth is usually from six to eight inches.

108. Why Subsoiling is Beneficial.—Subsoiling is beneficial because it produces effects somewhat similar to those spoken of under trenching.   They may be described as follows:

(1) It loosens the hard earth that lies below the reach of the ordinary plow, and thus favors the escape of water and the circulation of air in the soil.

(2) It provides a deeper foraging ground for the roots of plants, and since these by their growth and decay add to the quantity of the soil, it therefore adds to the depth of the soil.

(3) It secures crops against drought by enabling the roots to penetrate into the region of a lower moisture.

109. When Subsoiling is Beneficial.—The best time for subsoiling is determined largely by the nature of the land. It is hurtful to any land if done when the soil is wet. The injury arises from what is called "puddling," which leaves the subsoil less favorable, even than before, to the percolation of water and air and to vegetable growth. Ground is in the best condition for subsoil plowing in the autumn; but if it be done then much of the benefit that would be derived from it will be lost, because of the settling of the loosened subsoil in the winter. To obtain the best results from subsoil plowing at any time, the land should be well underdrained.

CHAPTER VI.

Tillage: Preparation of the Soil for Seed.

110. Principal Operations and Their Object.—The principal operations in preparing the soil for the seed are *plowing*, *cultivating*, *harrowing*, and *rolling*.

The object of these operations is to improve the immediate productiveness of the soil, so that the plants intended to be grown upon it may easily obtain from it the supply of plant food necessary for their growth and maturity.

They effect this:

(1) By deeply stirring and loosening the surface soil, so that the roots of the plants can freely extend themselves in search of food.

(2) By opening the soil, so that air and water can readily penetrate it and convert inert materials into soluble, and hence available, plant food

(3) By pulverizing the soil, so that its power to draw moisture from the subsoil below (that is, by capillary attraction) and to retain it, is increased.

(4) By thoroughly mixing the soil, so as to effect an even and equal distribution of manure.

(5) By destroying weeds.

(6) By disturbing insect enemies and bringing them to the surface, where they are destroyed by unfavorable weather and by birds.

<div align="center">PLOWING.</div>

111. What Plowing is.—Plowing is the inversion of the soil by using an implement constructed for the purpose, drawn by horses or by oxen, or propelled by steam.

112. Object of Plowing.—The object of plowing is to clean the soil by burying weeds or grass, and to prepare (that is, in part) a bed for the reception of the seed. In plowing, the larger the amount of surface exposed to the atmosphere, the more perfect is the operation considered. In practice this is found to be when the furrow-slice is square cut, when its width is to its depth as about 10 to 7 inches (in practice, often about 9 inches in width and $6\frac{3}{10}$ inches in depth), and when it is laid at an angle of about 45 degrees with the surface. On sod ground, the furrow is usually from 8 to 10 inches wide and from 5 to 7 inches deep.

113. Points of Merit in Plowing.—The chief points of merit in good plowing are :

(1) A straight furrow of uniform depth and width.

(2) A clean cut as to the furrow, both on the side next the unplowed land and on the floor or bottom ; and hence correspondingly clean cuts on the exposed edge and top of the inverted slice.

(3) The complete burial of the grass and stubble turned over.

(4) A ridge even and uniform, with a finish showing an open furrow with a clean narrow bottom. The last furrow-slice should be about equal in width and height with the others.

When, in plowing, the depth of the furrow is not uniform, the subsequent operation of harrowing will not furnish a uniform depth of fine tilth for the seed-bed, and the seed will therefore be buried at unequal depths.

For the purpose of burying weeds and grass, there may be used, with considerable benefit, a tiny plow-shaped piece of metal in front of the coulter, called a "skimmer." For the

same purpose also may be used a short heavy chain, with one end fastened to the beam of the plow and the other to the end of the double-tree of the off-horse. The slack of the chain should be made to move just in front of the turning furrow-slice.

In burying crops intended to be used as green-manures, it is often necessary, before plowing them under, first to go over the ground with a roller.

114. Feering, or Striking-out.—*Feering,* or *striking-out,* is the term applied to the opening of a "land" or ridge. Where there is an old furrow to go by, two shallow furrow-slices are first turned upon the track of the old furrow, the one toward the other. Where there is no old furrow to go by, the striking-out consists in opening a new furrow, the plow going up and down the field once, turning shallow slices outward *from* one another. The plow is then made to turn the slices (with a portion of the underlying ground) back again *toward* one another, as in the first instance.

In practice, it is usual to plow about two-thirds of a ridge first, the turning being done to the right-about, and then to proceed to the next ridge and to plow about two-thirds of it. Then the space between the two ridges is completed by turning to the left-about.

115. Ribbing Land.—*Ribbing land* consists in turning two furrow-slices together over an intervening width of about 12 inches or more. On the ridgelets thus made, if exposed during the winter, the frosts exert a disintegrating effect. Clay land is much improved by ribbing it thus.

116. Depth of Plowing.—The depth to which land should be plowed is to be determined by the nature of the soil, the kind of the crop to be grown, the time of the year at which the plowing is done, and the probable effect of the plowing upon the weeds to be destroyed.

Shallow plowing is to be preferred when shallow soils lie upon an inferior subsoil; when in the spring hard clays are to be turned up for a crop to be grown the same season; when the object of the plowing is to kill thistles; and when the ground is to be turned over just after harvest, for the purpose of destroying weeds.

When, in the spring, stiff land is plowed deeply to be sown at once, the raw nature of the soil (see section 44) is unfavorable to strong growth.

Deep plowing is preferable in sandy soils, and in those containing a large amount of humus (see section 34), provided they be well-drained ; and also in the case of a summer-fallow, for in summer-fallowing the raw soil turned up from beneath has time to be improved by exposure to the atmosphere.   In the cultivation of wheat and of root crops, deep plowing should always form some part of the preparatory process.

As a rule, it is much better to plow deeply in autumn than in springtime ; this is owing to the beneficial influence of the weather during winter on the upturned soil (see next section).

117. Treatment of the Subsoil.—The subsoil should be brought to the surface in small quantities at a time, and only in the autumn or in conjunction with summer-fallowing ; the reason for this is that *time* is necessary in order to convert (through the influence of the atmosphere, rain, snow, etc.) the raw inert material of which the subsoil is composed into available plant food.

118. Time for Plowing.—The *time* at which plowing should be done depends upon the objects aimed at, and the nature and condition of the soil.   For all kinds of cereal growth, the best time for plowing is in the autumn ; the reason being that the exposure of the soil to the influence of the air and weather during the winter season results (with but little other preparation) in a suitable seed-bed, warm and loose, in the spring, and moreover gives opportunity for sowing early.   For a similar reason, whenever possible, stiff clays should be plowed in the fall. As a rule, the gang-plow should not be used in the spring on fall-plowed lands, as the warm and fine surface soil, prepared by the winter's exposure, should be kept on top, so that the seeds when sown may be stimulated to grow at once.

Plowing soils when they are over-moist should be avoided ; lest "packing" results.   This is especially true of clays ; for when these are plowed in this condition in the spring the crop is seldom a good one.

119. Rate of Plowing.—Under average conditions, a span of horses should plow an acre of sod land in nine hours. They will travel eleven miles in doing this much. As about one-fourth of their time is spent in turning, it is more economical to have fields laid out long rather than broad.

CULTIVATING.

120. What Cultivating is.—By *cultivating* is meant the loosening, stirring, and mixing of the soil, by implements somewhat resembling plows, called "cultivators," which, however, do not *invert* the soil as is done in plowing. In cultivating, the soil is sometimes stirred to the same depth as in plowing, but this is not usual. When cultivating is applied to growing crops, it is termed *horse-hoeing*.

121. Objects Gained by Cultivating.—Among the objects gained by cultivating (as distinct from plowing and harrowing) are:

(1) It retains on the top of the soil the fine tilth which winter-weathering produces on the surface of fall-plowed lands; and thus, because of the warmth and moisture which this tilth holds, and the availability of its plant food, it secures a quick start and ready supply of nourishment for the seed.

(2) On land, fall-plowed and spring-cultivated, the seed can be sown earlier than on land which is merely plowed (no matter by what process) in the spring only.

(3) By cultivating, bare-fallow and green-crop lands may be kept free from weeds, and, at the same time, loose and porous, at low cost.

(4) After heavy rains the cultivator will stir thoroughly, to a depth sufficient for any crop, a soil which, for many crops, the harrow alone would not be able to convert into a seed-bed deep enough.

122. Cultivating Green-Crops.—Green-crops (turnips, mangels, etc.), sown in drills, should be cultivated frequently. This process allows the air to penetrate the soil, and also enables moisture to reach it, both from the atmosphere and from the subsoil. The cultivator used in this work should have narrow

teeth or shares; while that used in bare-fallow, or for preparing
a seed-bed, should, in most instances, have broad shares, in order
hat all weeds may be cut.

123. Time for Cultivating.—Fall-plowed lands, to be
sown with spring grain, should be cultivated in the spring as soon
as they are dry.   Those sown with green-crops (turnips, mangels,
etc.) should be cultivated as soon as the plants are well above
the ground.   And with these crops, the more frequent is the
cultivating, until the plants are too large to admit of it any longer,
the more rapidly will the plants grow.   Clean pea-stubble
ground, intended to be sown with winter wheat without plowing,
should be cultivated as soon as the crop is removed; and the
process should be repeated once or twice.   With respect to the
cultivating of bare fallows, it may be said that they should be
gone over at convenient seasons, but often enough to remove all
signs of weed-life, and to secure a fine tilth by the time of sowing.

<div align="center">HARROWING.</div>

124. What Harrowing is.—By *harrowing* is meant the
process of stirring the soil by a toothed implement, drawn by
horses, called a harrow, for the purpose of securing a fine surface
for the soil, and oftentimes, also, for covering the seed which is
sown upon it.

125. Objects Gained by Harrowing.—Among the
objects gained by harrowing are the following:

(1) It reduces to fineness the surface lumps and clods left after
plowing or cultivating, and smooths the surface inequalities of the
soil, thereby securing a more even disposition of the seeds that
are to be sown upon it.   In other words, it is (with the
exception of *rolling*, which sometimes intervenes) the final
preparation of the soil before sowing.

(2) It greatly helps to destroy weeds in the early stages of their
growth.

(3) Like cultivating, it promotes aeration and the absorption
of moisture by reducing coarsely pulverized or clodded earth to a
more finely pulverized condition, and by making "packed"
earth porous.   Hence in the spring it is helpful on rain-beaten

surfaces sown with winter wheat, since it breaks up the crusted surface and allows air and moisture to get at the young wheat rootlets.

Moreover, harrowing is the principal means used for covering all seed not sown with a drill.

126. Time for Harrowing.—Harrowing is usually the last process of cultivation prior to the sowing of the seed; and it always follows seed sowing, except when the drill is used. As other instances of suitable times for harrowing, it may be mentioned that corn should be harrowed when it is from two to four inches above the ground; fall wheat, with which grass seed is sown, should be harrowed in the spring as soon as the ground is dry; newly sown grain-fields, whose surfaces are encrusted, owing to heavy rain-falls, as soon as they are dry enough; and old pastures, when the object is to renovate them, early in the spring.

127. Fineness of Tilth in Harrowing.—As a rule, seed-crops sown in soils having a fine tilth, that is, in seed-beds which have been finely prepared, give far the best results; but there are a few exceptions. Winter wheat, sown upon clay soils, resists the action of bleak winds better when upon the surface of the land some small clods have been left.

128. Methods of Harrowing.—Lands plowed out of stubble should be harrowed first lengthwise once or twice, and then crosswise. On sod-plowed land the crossing should be done obliquely (that is, not at right angles to the direction of the first harrowing). This prevents the turning of the sods back again.

129. Kind of Harrow to be Used.—The kind of harrow that should be used will depend largely on the object aimed at. In heavy soils the harrow should be heavy; but in light soils it should be light, but large enough to cover a wide strip of surface at one passage or "stroke." For the purpose of covering light seeds, as, for example, grass seeds, a smoothing harrow is best.

ROLLING.

130. What Rolling is.—By *rolling* is meant the process of

smoothing and packing the surface of the soil by means of an
implement drawn by horses, called a roller, made principally of
a solid cylinder of wood or of a hollow metal cylinder.

131. Objects of Rolling.—Some of the objects of rolling
are:

(1) To compress the surface of the soil so that the harrow will
do its work more efficiently; also to break such clods or lumps
as may have resisted the action of the harrow.

(2) To smooth the surface of the soil for an even distribution
of fine seeds; and by pulverizing and packing the ground make
it so firm and close around such seeds that they will sprout
readily.

(3) To press into the ground the roots of plants partially
dislodged by frost.

(4) To give more compactness to soils that are light and
friable, and thus check undue evaporation.

(5) To remove the conditions favorable to the development of
many kinds of insects.

(6) To sink surface stones so that they will not hinder
harvesting operations.

132. Time for Rolling.—Light and porous soils may be
rolled at any time, whenever the requirements of cultivation
demand it, but clay soils can be rolled to advantage only when
they are stiff and cloddy. Meadow lands should be rolled in
the spring, as early as the process can be effected without
"poaching," that is, the making of holes in the ground by the
sinking of the hoofs of the horses; else the rolling will be
ineffective. Spring grain, in ordinary weather, should be rolled
as soon as it is sown; but in time of wet weather the rolling
should be deferred until the grain is above the ground; in the
first case, quick sprouting is assisted, and in the second, surface
encrustation is avoided. Autumn sown grain should not be
rolled after sowing, lest fall rains pack the soil.

CHAPTER VII.

Tillage: The Rotation of Crops.

133. What is Meant by Rotation of Crops.—By rotation of crops is meant the adoption of a fixed order of succession with respect to the various kinds of crops intended to be grown on the same plot of soil, so that the same kind of crop shall be raised on one plot of soil at regular intervals only.   The length of the period of rotation will correspond, of course, to the length of these intervals.

134. The Necessity for Rotation of Crops.—The necessity for rotation of crops is based upon the fact that when one kind of crop is grown for a long time upon the same piece of land, the soil at length becomes exhausted of those kinds of plant food upon which that crop feeds.   There is not the same imperative necessity for rotating crops that there was in former times, for the reason that artificial fertilizers, specially adapted to the needs of any desired crop, can now be easily secured whenever required.   Therefore, it is possible for a person living near a good market, by the use of suitable fertilizers, to grow with profit on the same piece of land the same kind of crop for a long term of years, while formerly it would have happened that with each successive crop the yield would have become smaller and smaller, until finally the land would have refused to produce that kind of crop at all.

135. Benefits of Rotation. —The following are some of the benefits arising from the adoption of a suitable rotation:

(1) *It economizes the natural supplies of fertility contained in the soil.*   Different crops feed upon different soil ingredients, or at least they require these ingredients in varying quantities.   A proper succession of crops brings all the elements of plant food into use, and hence prevents any of these from lying idle and being wasted; as, for example, by being carried away by water in its constant percolation through the soil.

(2) *It economizes applied manures, by making use in due time of all their fertilizing ingredients.* When fertilizers are applied to a soil, it will generally happen that any one kind of crop will not be able to make use of all the elements of plant food which they contain ; and the more general these fertilizers are in their character, the less will be the capacity of any single crop to use all their plant food components. When, therefore, soils treated with artificial fertilizers are deprived of the benefit arising from a proper rotation of crops, there is even a greater waste of plant food than would happen were merely unmanured soil deprived of their benefit.

(3) *It tends to the enrichment of the surface soil.* This is owing to the variety of modes in which plants obtain their food. Some plants, as, for example, beans, peas, etc., draw large supplies of plant food from the air ; and others, as certain of the clovers, gather much plant food deep down in the subsoil. But by the decay of rootlets and their consequent change to soil, and for the reason that much of the plant food contained in crops is returned to the soil again as manure, it follows that the surface soil, when under proper cultivation, is being constantly enriched by stores of plant food obtained both from the subsoil and from the air. Therefore, when various crops are made to grow in succession on the same plot of soil, the enriching process is more complete (that is, plant food is added to the surface soil in more even proportions) than if only one kind of crop were grown.

(4) *It enables the labor of the farm to be carried on in a proper order, and to be evenly distributed over the various seasons of growth.* When several crops are grown, each ripening at a different period, it is easier to care for them properly, and the labor of caring for them costs less, than if but one or two varieties are grown.

(5) *A regular succession of crops is helpful in keeping the soil free from weeds.* The rotation adopted usually embraces a bare fallow or some kind of hoed crop, both of which conduce to this end. If the same kind of crop were grown year in and year out, the weeds which grow most readily along with that crop would

soon (unless great labor were spent in checking them) take entire possession of the soil.

(6) *Rotation of crops improves the mechanical texture of soils.* When sod surfaces or green crops are turned under (as invariably happens sometime or other in every well-chosen scheme of rotation), an ameliorating effect on the soil is sure to follow. Even where it is desirable to grow, through the aid of artificial manures, the same crop for a term of years, it would still be well to grow a green crop occasionally, for the purpose of improving the texture of the soil.

(7) *The increase of destructive insects is hindered by rotation of crops.* When but one kind of crop is grown, the conditions favorable to the growth of the insects which feed upon that crop are continued unchanged from year to year.   But when another crop is sown and cultivated, the conditions are changed, and the insects which the former conditions favored are more or less destroyed.

(8) *Rotation is a necessity for the economical feeding of live stock.* In the keeping of live stock, it is necessary to feed them with a variety of crops, and, from what has been said above, it will be seen that these can be grown more cheaply when a proper rotation is observed than would be at all possible otherwise.

136. Examples of Rotations Suited to Different Soils.

For *heavy clays* a *six years' rotation* may be adopted. A good order would be: (1) *wheat*, (2) *hay*, (3) *hay*, (4) *pasture*, (5) *oats*, and (6) *peas*.   In this rotation, peas, the crop at the end of any one period, will of course be followed by wheat, the crop at the beginning of the next period.   If the land should become foul, a bare fallow might be necessary, and this of course would modify the rotation.

On *clay loams* a *seven years' rotation* may be adopted, the order of which might be: (1) *wheat* or *barley*, (2) *hay*, (3) *hay*, (4) *pasture*, (5) *oats*, (6) *peas*, and (7) *green fodders, corn*, or *roots*. In this case, wheat will follow green crops, and these only.

On *sandy loams* a suitable *seven years' rotation* will be found in the following order: (1) *wheat* or *barley*, (2) *hay*, (3) *pasture*,

(4) *corn*, (5) *oats*, (6) *peas*, and (7) *green fodders* or *roots*.   In this rotation, the corn and the root crops effect the purpose of bare fallows.

On *light soils* or *gravelly soils* an alternating rotation (that is, a rotation consisting of two parts) would probably be the best. The first part might consist of: (1) *wheat*, *rye*, or *barley*, (2) *hay*, (3) *pasture*, and (4) *corn;* and the second of: (1) *barley*, (2) *hay*, (3) *oats*, (4) *peas*, and (5) *roots* or *green fodders*.

The rotations here given are intended to serve only as general guides; in each case various other rotations might be adopted that would give equally good results.

137. Some Conditions that may Modify the Application of the Principle of Rotation of Crops.—(1) *The kinds of live stock kept, and the systems of managing them that are adopted, may affect it.*   Each kind of stock requires its own special kind of food, which therefore must be provided; and, moreover, when, in summer, live stock are fed inside, special crops must be grown to feed them, quite different from the ordinary produce of the pasture field.   Therefore, upon the introduction of any one kind of stock, it would likely happen that a change would have to be made in the scheme of rotation to provide the special food required for that kind of stock; and other changes would probably have to be made when other kinds of stock would be introduced.

(2) *It may be affected by the demand for crops and the obtainable market values of these.*   Where prices are brisk for any particular kind of crop, that crop should, if possible, be frequently grown.

(3) *It may also be affected by soil and by climate.*   For example, in *heavy and stiff soils* the rotation in general use might sometimes be advantageously modified to secure a more frequent occurrence of *wheat* and *grass;* while in *light and free soils* the rotation ought to be modified to secure as frequently as possible *spring grains*, *roots*, and *fodders*.

(4) *It may be affected by the state of the farm in respect of weeds.*   When the farm is foul with weeds, it may not be advisable to carry out fully any fixed scheme of rotation; for those crops should receive most attention that will aid in cleaning the farm.

CHAPTER VIII.

The Crops of the Farm: Their Growth and Management.

138. What Crops Should be Grown.—The kinds of crops that should be grown on any farm, and the proportion of each that should be grown, will depend upon a number of conditions. The principal of these are the climate of the locality, the soil of the farm, the market facilities available, the condition of the live stock and dairy interests of the time, and the pecuniary needs of the farmer. It is evident that it is not wise to attempt to grow a large acreage of any kind of crop ill-suited either to soil or climate; and where the market facilities are not good, cereal crops should not be grown for direct sale, but rather for feeding stock. There should also be grown for the stock such other sorts of food as they require. But what sorts must be grown, and the amount of each, must depend on the kinds of stock kept on the farm, and their various requirements. Notwithstanding all this, the pecuniary needs of the farmer may compel him to grow the crops that will bring him the speediest returns, without respect to any other consideration.

139. The Principal Farm Crops.—The principal farm crops that may be grown with advantage in Ontario are *hay, pasture, wheat, rye, barley, oats, peas, turnips, mangels, carrots,* and *potatoes.* In addition to these are the *soiling crops,* but these will be treated of in a separate chapter.

HAY.

140. Importance of Hay.— Hay forms an important feature in any ordinary system of rotation. This is owing partly to its value for feeding stock and partly to the improvement which its growth and cultivation effect in the texture of the soil.

141. Leading Varieties.—Timothy, the common red clover, mammoth clover, and alsike clover, are the leading sorts

of grasses sown to produce hay. These are sometimes sown separately, but commonly the practice is to sow them more or less mixed. In addition to these four kinds of grasses, which from their importance may be called the *staple grasses*, there are other varieties, such as orchard grass, lucerne, fescue, etc., which are sometimes mixed with the former four, or with one or more of them. When such a mixture is sown, the resulting crop is called *mixed grasses*.

142. Favorite Soils.—Hay will grow on almost any kind of soil that is dry; but a clay loam, with a fairly open subsoil, is the one best adapted to its growth. Clay soils produce good crops of hay, but sometimes it is not easy on them to "get a catch" with the seed. Light sands and gravels yield small crops, and such as they do produce are poor in quality. Timothy grows best on rich moist soils, abounding in humus. The clovers do best on drained soils having a deep subsoil. Lucerne requires dry and deep loams. Orchard grass grows well in shady places.

143. Place in the Rotation.—Hay, whether from the "staple grasses" or from the "mixed grasses" (see section 147), should follow in the rotation a hoed crop, or a bare fallow, because in those cases the land is clean. The seed is generally sown along with some kind of grain, such as wheat, barley, or rye. Of these, barley is the most suitable, owing to its growing more quickly and less densely than the other grains.

144. Preparation of the Soil.—The chief thing to be aimed at in the preparation of the soil is to get it fairly rich and in a clean and finely pulverized condition. It is a serious mistake to sow grass seed on soil which is dry and lumpy.

145. Quantity of Seed Per Acre.—The quantity of seed required per acre varies, good soils needing less than poor ones. When the staple grasses are sown together, the following are fair average quantities:

Of timothy, from 4 to 6 lbs. per acre.
Of common red clover, 3   "   "
Of alsike clover,   2   "   "
Of mammoth clover,   1   "   "

These quantities will vary somewhat with the objects aimed at in producing the crop, and also with the state of the soil.

146. Time for Sowing.—Timothy is sown sometimes in autumn, sometimes in the spring; when sown in the autumn it is usual to sow it with fall wheat. All other grasses are sown in the spring, generally along with some kind of grain, the seeder being attached to the grain-drill. The seed should fall behind the drill, and be covered merely by the roller. But when sown in the spring, with a crop of fall wheat, grass seed should be thoroughly covered by means of a light harrow.

147. Mixed Grasses.—A larger bulk of hay, also hay that is finer in quality and more nutritious, is usually obtained from a meadow composed of mixed grasses (see section 141) than from one composed of the staple grasses alone, and the only extra outlay entailed is the increase in the cost of the seed. The varieties sown may comprise, in addition to one or more of the staple grasses (timothy generally being preferred), a selection from the following:

> Lucerne,
> Orchard grass,
> White clover,
> Yellow clover, or trefoil,
> Kentucky blue grass,
> One or more of the oat grasses,
> One or more of the fescues,
> One or more of the rye grasses,
> Meadow foxtail,
> Red top.

But few soils are adapted to the growth of all these. Experience, therefore, should guide in the selection. Of seed, usually not more than 12 to 18 pounds per acre of the entire mixture is required, although some authorities recommend a much larger quantity. With respect to sowing, substantially the same method may be adopted as in sowing other grasses.

148. Time for Cutting.—*Clovers* should be cut when in full bloom, and *timothy* in what is termed the first bloom. As all grasses do not ripen at the same time, it follows that when

mixed grasses are grown, the time of cutting must be chosen so as to suit the grasses that are most important in the mixture, and, moreover, the components of the mixture should be chosen so that, as nearly as possible, all the sorts may ripen together. For example, as orchard grass ripens with red clover, it should not be sown with a crop in which timothy is the main factor.

149. Curing Hay.—In the making of first-class hay, exposure to sunlight, dew, and rain, must, as far as possible, be avoided. For this reason, the best quality of hay is obtained when the cut grass is put in cocks as soon as it is dry enough, and is allowed to remain until it has dried so as to be in fit condition for storage before it is drawn in. While in the cocks a mild fermentation takes place, and this fermentation improves the hay; the reason being that the transpiration of moisture which the fermentation causes continues for a time, and prevents crispiness. But during the whole process of curing, exposure to rain must, if possible, be avoided, because the rain dissolves and washes out a portion of the soluble food ingredients which the hay naturally contains, and moreover renders it less digestible.

The above process of curing hay is being superseded by the process of "rapid curing," as it is called ; that is, tossing the hay in the air by means of the "hay-tedder," raking it into winrows, and drawing it directly from the winrows into the barn. By this rapid method, the hay is cured with less labor and with less risk than by the slower method. If the hay should be a little damp when put into the mow, the application of a little salt will check undue fermentation, and so prevent the moulding which the fermentation would produce.

<center>PASTURES.</center>

150. Temporary and Permanent Pastures.—Pastures are of two kinds, temporary and permanent.

Temporary pastures are those which are used during only a limited period, sometimes not more than one year. These, in a scheme of rotation, generally follow the hay crop at the end of the first or second year.

Permanent pastures are those which occupy the same lands for

a long term of years to the exclusion of all other crops. They may include but one variety of grass, or a number of varieties. Permanent pastures which are largely made up of the foreign grasses (see section 147) do not succeed so well in Ontario as in some other countries: this is because the drought of our summers and the cold of our winters are too severe for them. They may be grown with profit, however, on low-lying, well-drained loams that are rich in humus; but they do badly on dry, sandy, or gravelly soils, and on stiff clays.

151. What Varieties of Grass Should be Chosen in Establishing a Pasture.—As temporary pastures are usually the fields from which one or more crops of hay have been removed, no special selection is made for them. But for permanent pastures (that is, when established on arable land) a special selection of seed should be made, different from that used for a hay crop. The seed sown may include a number of the varieties mentioned under "mixed grasses" (section 147), but prominence should be given to those that are long-lived and hardy. Experience has shown that the fescues, rye grasses, and oat grasses, should be sown with caution, as they are apt to die out early. Timothy and orchard grass should always fill a prominent part in the mixture sown, while red clover should be omitted altogether, as it is a biennial, and dies out after the second year. *The quantity of seed* of the entire mixture to be sown should not be more than from 15 to 20 pounds to the acre. A less quantity will sometimes suffice.

152. Temporary Pastures Preferable to Permanent Pastures.—In Ontario, it has been found, in respect to pastures, that land that is *arable* yields better results when resown at short intervals than when kept in grass for a long term of years. In other words, experience has shown that temporary pastures are more profitable than permanent pastures.

WHEAT.

153. Importance of Wheat.—Among the crops of the farm, wheat holds the first place, since it fulfils the conditions required for human sustenance better than any other grain.

154. Leading Varieties.—Of wheat there are many different varieties, but they may all be classified as being either

red or *white*, or as *bearded* or *beardless*, or as *winter* or *spring*. But these classes are not fixed; they are capable of modification under certain circumstances. For example, in some climates winter wheat may be converted into spring wheat by repeatedly sowing the seed a little earlier every year; and, contrariwise, spring wheat may be converted into winter wheat by sowing the seed a little later every year. Again, as regards color, wheat is greatly influenced by soil and climate. White wheats become red when repeatedly grown for a long period on cold soils, and the red varieties become white when grown for a long time on rich, warm soils. The color of the straw changes more slowly than that of the grain; hence, we have sometimes a red grain with white chaff and straw, and sometimes a white grain with red chaff and straw. Red wheats are hardier and more easily grown than the white varieties, but are seldom equal to them in quality.

155. Favorite Soils.—Wheat will grow on nearly every sort of soil that is in good condition, but it is most at home in a deep loam which inclines to clay and possesses a dry subsoil.

156. Place in the Rotation.—In a well-ordered scheme of rotation, winter wheat should follow a bare-fallow, or peas, clover, or a soiling crop. Spring wheat should follow a hoed crop. The advantage of having peas or clover precede a wheat crop is this: these crops bring to the surface soil, where the wheat rootlets can make use of it, valuable nutriment from the air or from the subsoil (see section 135 (3)); moreover, these crops improve the soil mechanically, and make it better suited to the growth of wheat.

157. Preparation of the Soil.—In the preparation of the soil for the growth of wheat there should be deep cultivation, but this need not immediately precede the sowing of the seed. The tilth for spring-sown wheat should be fine; but fine tilth is not so necessary for winter wheat. After a pea crop, if the land be clean, cultivation without plowing is well suited to winter wheat, and after a root crop, to spring wheat. When wheat is intended to follow clover, the plowing should be done as soon as the second cutting is well grown. To aid in giving the young

plants a vigorous start, the manure which is used should, at the time of sowing, be near the surface.

158. Quantity of Seed Per Acre.—The amount of seed required per acre varies with the nature of the soil and the method of sowing adopted; and indeed this holds true of nearly every kind of grain. When sown with the drill, from six to seven pecks per acre are sufficient, but when sown by hand, eight pecks are required.

159. Time for Sowing.—In Ontario, the best time to sow winter wheat is from September 1st to September 10th. When sown earlier, there will be too much top; and when sown later, there will be too little growth for the protection of the wheat rootlets during winter. Spring wheat should be sown as soon after winter as the ground is dry.

160. Time for Harvesting.—Wheat is ripe and fit for harvesting when the stalk immediately below the head becomes yellow.

RYE.

161. Importance of Rye.—The importance of rye as a farm crop lies in the fact that it furnishes a valuable grain food for live stock, and that it will grow on soils too poor for producing good crops of wheat.

Rye is grown only in the temperate zone, and succeeds best in northerly latitudes. Good crops of rye have been produced on the surface of a frozen subsoil.

162. Leading Varieties.—In Ontario two leading varieties are known, *winter rye* and *spring rye*. Of these, winter rye is much more largely grown than spring rye, the latter having a shorter straw and a smaller grain, and being less productive.

163. Favorite Soils.—The soils best adapted to rye are light sandy and gravelly ones. Soils too light for wheat will produce good crops of rye; but on stiff clays rye does not do so well as wheat.

164. Place in the Rotation.—Rye should occupy the same place in the rotation as winter wheat, but it will grow on land less carefully prepared. When grown as a soiling crop, it may occupy any place in the rotation.

165. Preparation of the Soil.—The preparation of the soil for winter rye is much the same as that required for winter wheat. Spring rye is hardly ever grown in Ontario.

166. Quantity of Seed Per Acre.—When sown with the drill, from six to seven pecks per acre are required; when sown by hand, eight pecks. When sown for a soiling crop more than this is required.

167. Time for Sowing.—Winter rye should be sown about the same time as winter wheat; but a later time will do, owing to the greater hardihood of rye. As said above, spring rye is hardly ever grown in Ontario.

168. Time for Harvesting.—Rye is ready for harvesting when the straw has changed in color, from green to a palish yellow, except at the knots, or nodes. Unlike wheat, rye does not shell easily when ripe.

BARLEY.

169. Importance of Barley.—Barley is useful as part of the grain ration in feeding milch cows, and when steamed or boiled it is frequently fed with good results to horses and swine. But of barley grown in Ontario, the principal part is used in making malt.

Barley is successfully grown in both the torrid and the temperate zones, and even on the borders of the frigid zone. The climate of Ontario suits it well.

170. Leading Varieties.—There are three distinct species of barley, the two-rowed, the four-rowed, and the six-rowed, and of each of these species there are several varieties.

171. Favorite Soils.—The soils best adapted to the growth of barley are strong calcareous and friable loams.

172. Place in the Rotation.—Barley generally follows a root crop, a corn crop, a potato crop, or a soiling crop, the reason being that it does best when sown on clean land that is in fine tilth.

173. Preparation of the Soil.—The land for barley should be in the best of tilth, as it is a rapid-growing crop; and as its power of root development is much inferior to that of wheat, it is important that abundant stores of plant food suited

to it should be found near the surface of the soil in which it is grown. For this reason, the application of artificial fertilizers is very helpful.

174. Quantity of Seed Per Acre.—The quantity of seed to be sown per acre is about the same as in the case of wheat (see section 158).

In sowing barley, it is often beneficial to use seed which has been obtained from a crop grown on a different soil from that of the land intended to be sown. This is called "changing the seed." A change of seed is beneficial to any kind of crop, but it has been found to be especially beneficial in the case of barley. The change should be from lighter soils to heavier ones, and the reverse.

175. Time for Sowing.—Barley may be sown as soon in the spring as the land is quite ready. When so sown the frost may produce some injury, but usually the injury is not serious.

176. Time for Harvesting.—Barley should be cut rather under-ripe than over-ripe. This is to secure a bright color in the grain. The nature of the soil also influences the color. Sandy loams produce the brightest barley. It should be said, too, that the brightness of barley is much injured if, after cutting, it is exposed to rain or excessive dews.

OATS.

177. Importance of Oats.—Since oats are grown largely both to supply food for man, and as provender for horses and other animals, they are a very important crop. They do best in a climate somewhat moist, with a temperature neither too hot nor too cold.

178. Leading Varieties.—Oats are of many varieties; but the varieties cultivated in Ontario may be divided into three groups, namely, white oats, black oats, and grey or dun oats. In the black "tartarian" variety, and also in some other varieties, the grain hangs on one side of the straw.

179. Favorite Soils.—Oats thrive best on friable soils; but they grow fairly well on good clays, and moderately well on peaty and gravelly soils. They feed ravenously on decomposed vegetable matter.

180. Place in the Rotation.—In the rotation oats may follow pasture or hay, and they may precede a summer-fallow, or a root crop. They should, however, not come after a hoed crop, since, owing to their leafy habits of growth, they are apt to smother the grass which, if they were sown after a hoed crop, should be sown along with them.

181. Preparation of the Soil.—The preparation of the soil for oats is very much the same as that required for spring wheat or barley, though the ground for oats does not require to be in such fine tilth as that required for barley. Owing to the fact that oats will grow and thrive where barley and wheat fail, they are often unwisely subjected to neglectful treatment.

182. Quantity of Seed Per Acre.—As with other grains, the quantity of seed will vary with the condition of the land; but, when sown with a drill, about eight pecks per acre are needed, and when sown by hand, ten pecks.

183. Time for Sowing.—The best time for sowing is in the spring, at the earliest possible moment after the land has become sufficiently dry.

184. Time for Harvesting.—The best time for cutting oats is when the color first changes beneath the branching part of the stem that supports the grain, although at that time the stalk below may be green. When cut at this stage the ripening process will go on the same as if the grain had been allowed to remain standing, and the straw will be of more value for feeding than if cut later.

PEAS.

185. Importance of Peas.—As peas are a very favorite food with many kinds of stock, and are also used to some extent as food for man, they constitute a crop of considerable importance. They are much grown in all temperate climates.

186. Leading Varieties.—The varieties of the pea are very numerous. They are distinguished by the length of the haulm, or stem, by the shape of the pod and the seed, by earliness or lateness in ripening, by their edible qualities, and by the color of the seed. This color varies, being, for example, besides white, grey, brown, speckled, and green. The colored varieties,

that is, those that are not white, are considered the more hardy.

187. Favorite Soils.—The soils most suitable for peas are those of a light, loamy, or marly character, although they do fairly well on clay loams and clays. Soils containing much humus induce too great a growth of stem.

188. Place in the Rotation.—Although in the rotation peas usually follow oats, they need not necessarily do so. They need not necessarily occupy any fixed place in the rotation. In most instances, they do well on inverted sod in the first and second years; and when so sown, the cut-worm and the wire-worm do not harm them so much as these pests do some other grains.

189. Preparation of the Soil.—The preparation of the soil for peas is very similar to that required for oats. When they are sown on sod land plowed in the spring, as they often are, the land should be plowed as early as possible.

190. Quantity of Seed Per Acre.—When sown with the drill, the quantity of seed to be used is, of the small varieties, about eight pecks per acre, and of the large varieties, from ten to twelve pecks per acre. When practicable, peas should always be sown with the drill; this is in order to secure such a covering of the seed as will prevent it from being washed up by the rain.

191. Time for Sowing.—Peas should be sown in the spring, and, as a rule, as early as possible. But in localities infested with the pea-bug, they should not be sown till late in May. When sown late, however, they are liable to mildew.

192. Time for Harvesting.—Peas should be cut when about two-thirds of the pods are yellow. On smooth land they are most easily cut with the pea-harvester.

TURNIPS.

193. Importance of Turnips.—Turnips are one of the most important crops the farm produces. This is because of their great value for feeding young stock, and also on account of their value for fattening purposes. Moreover, their cultivation,

when properly conducted, effects great improvement upon the texture and cleanness of the soil.

194. Leading Varieties.—There are many varieties; and as with other cultivated crops, these are continually increasing in number. The best varieties have all sprung from a Swedish source.

195. Favorite Soils.—The soils that are best adapted to the growth of turnips are those that are free-working and loamy. Moreover, turnip-soils should be deep, capable of minute division, and be well-drained, and they should not contain an excess of humus.

196. Place in the Rotation.—In the rotation, turnips should come between two grain crops. They are often preceded by oats, and they should be followed by barley or spring wheat with which grass is sown as a succeeding crop.

In growing root crops, or potatoes, or corn, a field should always be selected that is in need of cleaning.

197. Cultivation and Harvest.—The following directions and observations respecting the cultivation and harvesting of turnips will meet the requirements of most soils, although variations will be necessary to suit certain differences of soil and other varying conditions:

(1) Immediately after the preceding crop is harvested, gangplow the field intended for the turnip crop. And in order, as far as possible, to destroy all weeds, harrow it once or twice.

(2) Either in the fall or in the spring apply barn-yard manure, at the rate of, say, fifteen loads per acre. Care should be taken that the manure be well-rotted, in order that all weed-life in it may be destroyed.

(3) Late in the autumn, plow the land deeply. In case there is a stiff subsoil, rib the land closely, running the subsoil plow between the ridges.

(4) If the land has been ribbed in the fall, then in the spring harrow it crosswise to tear down the ribs. After this, plow it *once*, before making the drills. If the land were not ribbed in the fall, then in the spring it should be plowed *twice* before making the drills.

(5) Then sow broadcast about 200 pounds each per acre of salt and plaster, and the same amount per acre of bone-dust, superphosphate (either bone or mineral), or blood manure.

(6) When the time for sowing arrives, which, as a rule, is from the 10th to the 25th of June, make the drills for the seed, using for the purpose a double mould-board plow, with a marker attached; the drills should be from 28 to 30 inches apart. Then sow the seed at once, the rate being from two to four pounds per acre.

(7) Ten days after sowing, if the subsoil be a stiff clay, run the subsoil-plow through between the drills. Then afterwards, as frequently as may be necessary, use the horse-hoe to destroy completely all weeds.

(8) As soon as the permanent or rough leaf is well-formed, single out with the hoe the plants that are to be preserved, making the intervals about 12 to 15 inches in length. Throughout the season keep the soil free from weeds.

(9) When the crop is ready to be harvested, cut off the tops with the hoe, and use the harrow for removing the roots from the ground; or else, pull and top by hand, throwing four rows into one.

(10) When the roots are finally stored in the cellar, care should be taken that no earth is allowed to be mixed with them. Great care also should be taken to secure proper ventilation.

MANGELS.

198. Importance of Mangels. —The mangel is considered a very important root for feeding stock. It is especially valued for the excellent food it furnishes dairy cows, breeding ewes, and pigs. It is frequently called the "mangel wurzel," and is supposed to have originated in a cross between the red and white varieties of the garden beet.

199. Leading Varieties. —The mangel is of several varieties. These are distinguished by their color, as red, orange, and yellow, and by their shape, as globular and oblong. With respect to these varieties, it may be said that the colors of the roots and of the leaves often differ more than the qualities of the plants.

200. Favorite Soils.—The mangel wurzel grows upon a wide range of soils; of which, however, light sands and stiff clays are the most uncongenial, especially the former. Well-drained soils of medium texture, with sufficient clay to give tenacity enough, and to provide the roots with the moisture and the mineral constituents they require, are the best. The globe varieties are best adapted to strong clays, or to shallow soils, and the oblong sorts to soils of more depth.

201. Place in the Rotation.—Like the turnip, the mangel wurzel, in the rotation, should come between two grain crops. When both turnips and mangel wurzels are grown, they may occupy the same place in alternate periods of the rotation.

202. Cultivation and Harvest.—The following directions and observations respecting the cultivation and harvest of mangels will meet the requirements of most soils, although variations will be necessary to suit certain differences of soil and other varying conditions :

(1) The cultivation in autumn may be the same as that for turnips, with the difference that in heavy soils the drills for sowing may also be made in the autumn.

(2) Where spring preparation is necessary, it ought to be done early.

(3) Barn-yard manure should be applied the same as for turnips, but always in autumn, in order that the sowing may be done as early in the spring as the state of the ground will permit.

(4) When artificial fertilizers are applied in addition to barn-yard manure, they may consist of from 200 to 400 pounds of salt, and 200 pounds of superphosphate per acre. These should be put on as in the case of turnips.

(5) As said above, the sowing should be done in the spring, and as early as possible. About 4 pounds per acre are required. The seed will grow more surely if, before sowing, it be soaked in water from 24 to 48 hours, and then be dried by the aid of ashes, sand, or powdered charcoal.

(6) When the plants are well up out of the ground, they should be thinned to distances of from 12 to 18 inches apart, according to the variety sown and the prospect of the crop.

(7) The subsequent cultivation of mangels resembles that described for turnips.

(8) Mangels are harvested before the time of frosts. If they are left for a few days in the field, in heaps covered by their tops, they will not ferment so much when put into the cellar. Mangels improve in their feeding qualities for some months after harvest.

THE CARROT.

203. Importance of the Carrot.—The carrot is a deep-growing root, much relished by live-stock. There is no kind of stock to which, in one form or another, carrots may not be fed with advantage; but they are especially good for horses, and to these they may be fed at the rate of from 10 to 25 pounds per day.

204. Leading Varieties.—The carrot is of several varieties, but the white varieties are the most suitable for field cultivation.

205. Favorite Soils.—The soils best adapted to the growth of carrots are those of a deep sandy or loamy texture; although some varieties (that is, those that are not so deeply rooted as the others) do well on both shallower soils and heavier soils.

206. Place in the Rotation.—In the rotation carrots properly come between two grain crops.

207. Cultivation and Harvest.—The following directions and observations respecting the cultivation and harvesting of carrots will meet the requirements of most soils:

(1) The preparation of the soil is very similar to that described for turnips and mangels, except that perhaps it should be deeper.

(2) In the fall the ground should be made as clean as possible, the reason being that, if the ground be not made clean, then in the spring the weeds are apt to get ahead of the young carrot plants and choke them.

(3) If, in addition to barn-yard manure, artificial fertilizers are applied, they should be similar to those described for turnips and mangels.

(4) The sowing should be done as early in the spring as possible. Early sowing is for carrots even more important than

for mangels. The drills for the seed should be from 18 to 24 inches apart.

(5) The amount of seed required per acre is from 2 to 4 pounds. If some turnip seed be sown along with the carrot seed, the young turnip plants will earlier show the lines of the drills, and so enable hoeing to be done at the earliest possible moment ; and this is important.

(6) The after cultivation of carrots is similar to that described for turnips and mangels, except that carrots should be thinned at distances of from only 5 to 9 inches apart.

(7) Carrots are generally pulled by hand, but in harvesting the deep-growing varieties a plow furrow run along the side of the drill makes the pulling of them easier.

<div align="center">THE POTATO.</div>

208. Importance of the Potato.—The potato is one of the most important crops the farmer grows. This is because it forms one of the chief articles of our food. It is also frequently used for feeding stock, especially swine.

The esculent part of the potato is not, properly speaking, a root. It is an expansion, or swelling, which is formed in certain parts of that portion of the stem which is underground. These underground expansions of the stems of plants are known *tubers;* hence the potato is often spoken of as a "tuber."

209. Leading Varieties.—The potato is of very many varieties, distinguished by shape, color, esculent qualities, and time of maturing. Those varieties that ripen early are the more often preferred, since they escape the rains of autumn, and are thus not in such danger of "rotting." As varieties become old they seem to deteriorate, and thus they are continually being replaced by newer varieties.

210. Favorite Soils.—The potato will do well on almost any kind of soil that is kept in a friable condition ; but it does best on those soils which are naturally deep, rich, dry, and porous. The soils most suitable for a very early crop are those which rest on a dry subsoil and vary from a sandy to a gravelly loam.

211. Place in the Rotation.—Like the root crops, potatoes in the rotation should come between two crops of grain, and so aid in cleaning the soil.

212. Cultivation and Harvest.—The following directions and observations respecting the cultivation and harvesting of potatoes will meet the requirements of most soils:

(1) From harvest time until winter, the land chosen should be cleaned as much as possible, the cultivation ending with a deep plowing.

(2) Barn-yard manure, wood ashes, lime, plaster, bone-dust, and superphosphate of lime, are the manures and fertilizers generally used. They are all useful, but of course they are not all equally suited to every kind of soil. As a rule, they should be applied in the spring; and the artificial fertilizers should not be applied till near the time for planting.

(3) Either early planting or late planting ensures, for the most part, better crops, and crops more free from disease, than planting at intermediate times.

(4) The furrows for planting are made with the plow; they should be three feet apart, and from four to five inches below the surface level.

(5) The tubers selected for seed are sometimes prepared for planting by being cut into pieces, each containing one or more buds, called "eyes." They are also sometimes planted without being so cut. Whether cut or entire, they are dropped into the drills one by one, at distances of about one foot apart. They are then covered, either with the plow or with the hoe.

If, a few days before planting, the seed potatoes be spread out upon a floor and sprinkled with lime, they will sprout more vigorously when planted.

Before the plants appear above the ground, a thorough cross-harrowing of the field with a short-toothed harrow will effectually destroy what would otherwise be the first crop of weeds, and will, besides, hasten the growth of the plants.

(6) Stirring the soil with the horse-hoe is almost the only kind of cultivation afterwards required. The hoe used for the purpose should have flat blades.

ʌ) The harvesting is done on *light soils* with a potato-digger, but on *heavy soils* it should be done with the plow and harrow. It should be remembered that exposure of the tubers to sunlight, even for a few hours, destroys their flavor and lessens their value.

(8) In the cellar, also, potatoes must be kept from the light; and the temperature of the cellar should not be above 45°.

213. The Colorado Beetle : Its Remedy.—The Colorado beetle is the great enemy of the potato; but a remedy for the pest has been found in a poisonous pigment called "Paris-green." Two successful modes of applying the remedy are as follows:

(*a*) Twice in the season spray the plants with a mixture of Paris-green and water, the proportion of the mixture being one ounce of *pure* Paris-green in 9 to 12 gallons of water.

(*b*) Instead of spraying the plants as above, "dust" them with a mixture of Paris-green and land-plaster, the proportion being one part of Paris-green in 50 to 100 parts of plaster. The dusting should be done when the dew is on the plants.

CORN.

214. Importance of Corn.—Corn is cultivated not only for its grain or seed, which is used as food both for man and live-stock, but also, and even more extensively, as a fodder-plant. And since the introduction of the silo (see section 471) its cultivation as a fodder-plant is rapidly increasing. No other crop grown in Ontario yields such abundant forage. The importance of corn, therefore, to the farmer who raises live-stock, is very considerable.

215. Leading Varieties.—The varieties of corn are very numerous. Some are better adapted to certain localities than others, so that experience alone can determine what selection of them should be made. For the making of ensilage (see section 471) the sweet varieties are frequently preferred.

216. Favorite Soils.—Corn is a deep-feeding plant. Hence it will do well on almost any soil that is fairly rich and deep, and well-drained; but it does best on a sandy loam that has a deep, free subsoil. It grows well, too, on clay loams which contain a good deal of humus. From its deep-feeding habit it is well fitted to withstand drought.

217. Place in the Rotation.—Corn, in the rotation, usually comes between two grain crops; but, since it feeds freely on decaying vegetation, it may also profitably follow meadow or pasture.

218. Cultivation and Harvest.—The following directions and observations respecting the cultivation and harvesting of corn will meet the requirements of most soils:

(1) Select for the cornfield one that requires cleaning, and after harvest is over, in order to destroy weeds, make use of late summer and autumn cultivation to the greatest possible extent.

(2) The manuring required for the cultivation of corn is somewhat similar to that described for the cultivation of turnips, though for corn the manure is more frequently applied in the spring than in the case of turnips. If the manuring be left till spring, unfermented manure may be used in case of necessity. When the plants have appeared above ground, gypsum is a favorite fertilizer. It should be sprinkled on the hills, or along the lines of the drills.

(3) In the spring, before planting, make use of thorough surface cultivation, for the purpose of destroying weeds and bringing the soil to the finest possible tilth.

(4) Corn is sometimes sown, sometimes planted by hand. The most common practice nowadays is to sow it with a grain-drill. When so sown, the rows should be from 30 to 42 inches apart. The seed required is from 10 to 16 quarts per acre.

(5) In Ontario, the best time for sowing or planting **corn is** from the 15th of May to the 10th of June.

(6) When the plants are a few inches above the surface, in order to destroy weeds, a thorough harrowing should be given to the soil. The harrow used for this purpose should have either short teeth, or teeth which are inclined backwards; this is to prevent the tearing out of the young plants.

(7) From that time onward, until the corn is too high for cultivation, the horse-hoe should be frequently used.

(8) If the corn is grown to be used as ensilage (see section 471), it should be cut when the grain is in the glazed state, that is, a few days before it is ripe. Making it into ensilage, and then

feeding it to stock as required, is the best and most economical method of using corn as a fodder.

219. Importance of Rape.—Rape, though extensively grown in Europe for the oil which is expressed from its seed, is in this country principally grown as a forage crop, and for this purpose its cultivation is extending. The especial value of rape is its suitableness for fattening sheep in autumn, and also, though in a less degree, for fattening cattle. Rape also is of great value as an aid in cleaning the soil. This is because that, being sown late, it allows the land to be worked as a summer-fallow before sowing, and that, after sowing, it admits of cultivation similar to that given the turnip.

220. Leading Varieties.—There is but one variety of rape grown in this country as a farm crop; this is usually known as "English fodder rape." But another variety, commonly called "bird rape;" is sometimes grown by apiarists. It is valued by them on account of the honey it produces.

221. Favorite Soils.—Rape will grow well on all soils that are adapted to the culture of turnips. It will also grow on soils that are peaty in their nature.

222. Place in the Rotation.—As rape is serviceable in cleaning land, it should come between two grain crops.

223. Cultivation and Harvest.—The following directions and observations respecting the cultivation and harvesting of rape will meet the requirements of most soils:

(1) Up to the time of the immediate preparation of the soil for sowing, the ground should either have been treated as a summer-fallow, or else in the previous autumn should have had rye sown upon it, which in the spring was pastured, cut for green-food, or plowed in as a green-manure.

(2) As in the case of turnips, the work of manuring should be carefully performed. When barn-yard manure is not to be had, superphosphate should be applied, at the rate of from 200 to 300 pounds per acre; also salt may be applied, at the rate of 300 pounds per acre. When the plants are up, gypsum may be applied, at the rate of from 100 to 200 pounds per acre.

(3) When the crop is intended for forage (which is generally the case in this country), the sowing should take place between the 15th of June and the end of the month, and the seed should be sown in drills. The quantity of seed required per acre is from ¾ of a pound to 2 pounds. When, however, the crop is intended as a green-manure, the seed is always sown broadcast, and the quantity per acre required is about from 2 to 4 pounds.

(4) The process of sowing and the after cultivation of rape may be the same as have been described for turnips, except that for rape less "thinning" is necessary.

(5) Instead of being harvested in a manner similar to other crops, rape is eaten on the ground where it grows. Sheep and cattle are turned into the rape-field to feed on the highly nutritious stems and leaves of the plant at will. But the stock should never be turned in when hungry, lest they eat to surfeit, and suffer from bloating.

CHAPTER IX.

Crops for Soiling.

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224. What is Meant by Soiling.—By *soiling* is meant that system by which green-food, grown for the purpose, is cut and brought to stock in their stalls, pens, yards, or paddocks, and there fed to them, so that but little or no pasturage is needed or made use of. Soiling may be either partial or complete.

Partial soiling provides green-food to supply a deficiency in pasturage in time of scarcity.

Complete soiling enables the farmer to dispense with pasturage entirely.

Soiling is well adapted to localities where land is scarce and dear, and also, as will be seen more clearly in the next section, to localities where there is a ready market for meat and dairy products.

225. Advantages of the Soiling System.— Among the advantages of the soiling system may be mentioned the following:

(1) *It effects a saving of land.* One acre of a soiling crop will usually furnish as much food for stock as that which three to five acres of pasture ground can supply.

(2) *It effects a saving in the outlay for fencing.* In complete soiling all the interior fences of the farm may be removed, except what are required for night paddocks for the different kinds of stock, and for a run for horses.

(3) *It effects a saving in food.* The food used in soiling is all eaten clean, without waste. Moreover, since in their labor of searching for food on scant pastures all kinds of stock waste flesh, the soiling system prevents this waste, and therefore effects a saving of food in a second way.

(4) *It increases the quantity and quality of manure made.* Much of the valuable part of the manure that is dropped in the pasture field is lost by being washed away by rain into running streams, or by passing off invisibly into the atmosphere, or by being destroyed by insects. The saving of manure effected by always feeding stock in confined places, where the manure can be wholly preserved, is estimated at fully one-half of the entire value of what is made altogether.

(5) *It beneficially affects the condition of the animals fed by means of it.* In a proper system of soiling the supply of food is always uniform and sufficient, and therefore the stock are saved from the injury arising from exposure to bad weather, and from the worry caused by flies.

(6) *It increases in a marked degree both the quantity and quality of the milk and meat products.* This arises from the abundance and suitability of the food which a proper system of soiling always ensures.

On the other hand, it may be said that the confinement which a system of soiling occasions may possibly, in course of time, be somewhat detrimental to the natural vigor of the stock. Therefore, the system should be used with judgment.

226. The Principal Soiling Crops.- The principal crops made use of in Ontario for soiling purposes are winter rye; red

clover; orchard grass; lucerne; timothy and clover; oats, peas, and vetches; millet; corn; and rape.

227. Winter Rye.—The advantage of winter rye as a soiling crop lies in the fact that it is the first to be ready for use in the spring.   It is usually cut but once, that is, just before or while in early blossom.   Moreover, immediately after the rye crop has been removed, a second soiling crop, as corn, or millet, may be sown upon the same ground.   Winter rye and clover may advantageously be fed together—the former being rich in carbo-hydrates (see section 18), and the latter being rich in albuminoids (see section 17 (4) (*a*)).

228. Red Clover.—Red clover generally proves to be an excellent soiling crop.   Its albuminoids and carbo-hydrates are well proportioned for the needs of young and growing stock, and it yields two cuttings a year.

229. Orchard Grass.—Orchard grass may advantageously be grown with clover, since both ripen for cutting at the same time.   It needs to be sown thickly, and, like red clover, may be cut twice a year.

230. Lucerne.—Lucerne is of peculiar value as a soiling crop where the land is suited to it.   It may be cut from two to four times a year; and, while in nutritive qualities it is about the equal of clover, it possesses the advantage of yielding a much greater weight per acre.

231. Timothy and Clover.—Timothy and mammoth red clover, when sown together, constitute an excellent soiling crop, the one making up in nutritive qualities what the other lacks.

Timothy and alsike clover, grown together, also make a good soiling crop.   Alsike branches out much in growing, and therefore need not be sown so thickly as other varieties of clover.   By beginning when the first alsike blossoms appear, this soiling crop may be fed for the space of three or four weeks.

232. Oats, Peas, and Vetches.—Oats and peas, oats and vetches, and, oats, peas, and vetches, all make good combinations for soiling purposes.   As regards time, they follow timothy and clover.   The quantity of seed per acre required of each is: oats, 1½ bushels; peas, ½ bushel; vetches, ½ bushel;

but these quantities may vary. These crops are best as green-food when the grain is in the milky state ; but nevertheless they may be used some days before they reach this stage.

233. Millet.—Common millet, when grown on rich soils, produces an abundance of stalks and leaves, both very suitable as green-food. It does best upon soils that are dry, rich, loamy, and well-pulverized. Millet is a quick-growing plant, leafy, succulent, and highly nutritious. It may be sown from May 1st to July 1st. It is ready for feeding shortly before blossoming, or while just beginning to blossom.

Hungarian grass and Italian millet are somewhat similar to common millet in their habits of growth and their feeding qualities.

234. Corn.—Corn is the most valuable of all crops for soiling purposes, and the one that yields the largest amount of food per acre. It is of a great many varieties, some sweet, many of them not sweet ; the sweet varieties are considered the most nutritious. For the cultivation of corn see section 218.

235. Rape.—Rape differs from other soiling crops in the fact that it is eaten on the land where it grows. When so eaten, it forms a valuable and convenient fattening food for sheep and lambs late in the season (see section 219).

236. Feeding Green-Crops : General Remarks.—When it can be managed, green-crops should be fed to stock in variety, since in this way one kind of crop often furnishes nutritive food constituents which another lacks. When the green-crops are unduly succulent, they are improved as food by being mixed with about one-fourth their bulk of straw. Also, a small amount of bran, or of oil cake, is a further improvement, from the fact that these foods aid in regulating digestion.

237. Feeding Green-Crops to Horses.—In feeding green-crops to horses, the chief requirements are :

(1) Feeding racks, suitably arranged in an open, accessible shed.

(2) An open woodland or other pasture, and a lane leading thereto.

For horses, any of the kinds of green-food mentioned in section 226 may be used, except rape.

238. Feeding Green-Crops to Cattle.—In feeding green-crops to cattle, the chief requirements are:

(1) A stable that is comfortable, clean, well-ventilated, and furnished with conveniences for feeding and watering.

(2) A yard attached, kept dry and well-littered, so that the stock may lie in it comfortably when the nights are hot. A sod field, easy of access, is even better than this.

239. Feeding Green-Crops to Sheep.—In feeding green-crops to sheep, the following are among the chief conditions to be observed:

(1) The number in each flock should not exceed one hundred.

(2) Each flock should be kept in an enclosure formed by movable hurdle fences.

(3) The enclosures should be moved once a week, both for the sake of cleanliness and that other portions of the land may be equally enriched.

(4) The sheep should be provided with light, portable racks, out of which they may feed. These should be placed along the sides of the enclosures.

(5) The enclosures should be placed so that water may naturally run through them; or else an artificial supply must be conveyed to them daily. Shade also should be provided.

(6) The green-food for feeding sheep should be cut when in a tender state. If a small quantity of grain be added to the green-food, it hastens the fattening process considerably.

240. Feeding Green-Crops to Pigs.—The most suitable green-crops for feeding to pigs are clover, or the mixture of peas, oats, and vetches. These crops may also be beneficially mixed with other foods.

241. Observations in Reference to Soiling.—The following general observations are offered:

(1) Every farmer keeping live stock should have recourse to soiling in order to meet the deficiency of food caused by short pastures in July, August, and September.

(2) The green-foods should be selected and sown so as to be ready for use at different periods following one another in regular succession.

(3) The plots chosen for the growth of the soiling crops should be located as near as possible to the stables, in order to lessen the labor of drawing the food to the stock.

(4) If the feeding be done in the stables, enough food may be drawn in at once to last two or three days, since wilting rather improves the food value of green-crops than otherwise.

(5) If cattle be fed green-crops in a field, the field should have a sod surface, in order that poaching may be prevented; and if the food be spread over a fresh surface every day, not only will the food be thereby kept cleaner, but the soil of the field will be more evenly enriched throughout.

CHAPTER X.

The Weeds of the Farm.

242. Some Evils Resulting from the Growth of Weeds.—Among the many evils resulting from the growth of weeds are the following:

(1) They rob the soil of its plant-nourishing constituents, both natural and applied.

(2) They tend to choke the useful crops amid which they grow, thus lessening the produce of these crops.

(3) In the farmer's efforts to destroy them he must often break in upon his regular schemes of rotation, and thus interfere with the natural productiveness of his land.

243. Weeds can be Subdued.—Weeds can be subdued, and if on any farm they are not subdued, the farmer's own apathy or indolence is to blame for it. If weeds that propagate themselves by their seeds (as all annuals and biennials) are prevented from ripening their seed, they must in the end all die out. If those which propagate themselves by their roots are kept from breathing the air by means of their leaves, they also must perish. Hence, if immediately when harvest is over, all grain-fields be gang-plowed once or twice, much is done towards

destroying the weeds of a farm. But, in addition, every field devoted either to grain or to grass must be gone over once or twice a year with the spud, if the farmer desires to keep his farm clean.

244. What Weeds are Most Troublesome.—The weeds that at present are most troublesome to the farmers of this Province are: the Canada thistle, wild mustard, wild flax, the wild oat, couch-grass, rag-weed, blue-weed, the ox-eye daisy, the burdock, and pigeon-weed.

245. The Canada Thistle.—The Canada thistle is a perennial plant, with a creeping root-stock possessed of many joints, every one of which is capable of sending out shoots, since upon each joint there is a latent bud. Thus this troublesome weed is propagated by its roots. Moreover, since its seed is attached to a downy substance by which the wind carries it easily from place to place, it is also propagated by its seed.

246. Methods of Destroying the Thistle.—Among the methods which experience has shown to be useful in the destruction of the thistle are: (1) Converting the infested field into a *summer-fallow;* (2) devoting it to a *hoed crop;* (3) taking from it *two soiling crops* in one season; (4) producing upon it a *heavy crop of clover.* The remarks concerning these various methods here offered are based upon successful experience:

(1) *The summer-fallow method.* When summer-fallowing is adopted for the purpose of ridding the land of thistles, let the autumn plowing be shallow, the share being kept above the horizontal thistle roots; since, if in the process of plowing these roots be brought near the surface, they will put forth shoots and propagate. The spring plowing should be similarly done, and it should be concluded before the young thistle plants are far above ground. For the remainder of the season a cultivator should be used of which the shares are broad enough, and set closely enough, to cut the whole surface of the soil.

When buckwheat is sown on the fallow, for the double purpose of smothering the thistles and enriching the soil as a green-manure, the sowing should be done in June; and the plowing-under should be done when the buckwheat is in blossom.

When rape is grown for the same double purpose, the sowing should be done late in June, the seed being sown broadcast; but if the rape be intended to be eaten as green-food, the seed should be sown in drills, as previously described (see section 223).

(2) *The hoed crop method.* When a hoed crop is resorted to for the destruction of thistles, the cultivation should be so thorough that never at any time will the thistles have a chance to get far above ground.

(3) *The two soiling crops method.* In this method the first crop should be rye, sown in autumn, and cut when in early blossom; the second crop should be rape, sown in drills.

(4) *The heavy clover crop method.* When this method is adopted it should, if possible, be made to follow one or other of the methods described under the three preceding subsections; and then, if a strong stand of clover can be secured, it will go a great way towards smothering any thistles that had previously escaped destruction.

247. Wild Mustard.—Wild mustard is an annual plant, with a stock or stem disposed to branching. It produces an enormous number of seeds, and these, owing to an oily coating with which they are endowed, retain their power of growing for many years. In this way it follows that the wild mustard is a very troublesome pest, being not only very prolific, but very hard to get rid of, since its seed may remain buried in the ground for years, and yet, being then by chance brought to the surface, will at once begin to grow.

Fig. 13. Wild Mustard.

248. Methods of Destroying Wild Mustard.—All methods for the destruction of wild mustard depend for their success upon the killing of the plant before it has had time to mature its seed. The following observations are offered:

(1) The infested field may be summer-fallowed, either simply, or in conjunction with two green-manure crops.

(2) Or it may be first summer-fallowed for one season, and then be devoted to a hoed crop. This method is very efficacious

(3) Or, when not too numerous, the plants may be removed by hand.

It should be a fixed rule on the farm that wild mustard should never be allowed to ripen into seed. Therefore, whenever practicable, the infested field should be cultivated so as to induce as many seeds as possible to develop into plants, and then these should be destroyed before they have time to produce seed in their turn.

249. Wild Flax.—Wild flax (or "false flax") is an annual whose pale-yellow flowers usually appear in June. It is chiefly troublesome in crops of hay, winter wheat, and rye, the reason being that it does not usually ripen in crops sown in the spring.

250. Methods of Destroying Wild Flax.—As the wild flax is propagated by its seeds, all methods for destroying it are based upon the necessity of killing the plant before it has had time to mature its seed. With this end in view, therefore, the following observations are made:

(1) The only method to prevent wild flax from ripening in fields of hay, winter wheat, or rye, is either to pull it up by hand, or else (as may be done in the case of hay, by using it as a soiling crop) to cut the crop before it is ripe.

(2) As this weed is chiefly troublesome in the crops mentioned in (1), above, the growing of spring crops on the infested fields tends to keep the weed in check.

(3) The infested fields may be summer-fallowed and then sown, the same season, with rape, in drills, thus allowing late cultivation.

(4) Or, they may be devoted to a crop of rye, grown for soiling or for green-manure, and then immediately afterwards to a crop of rape.

(5) Or, they may be devoted to pasture, care being taken to pull out by hand all the flax plants, as they appear, until the fields are clean. But this method is not completely efficacious, for, since the seeds are oily, they may remain for a long time in the ground, only to germinate when the field is again cultivated.

If care be taken in the selection of timothy seed to see that it is quite clean, much will be done towards preventing the

spread of this pest, since the wild flax seeds are often found in timothy seed.

251. The Wild Oat.—The wild oat is a very hardy annual, bearing no little resemblance to the common oat.

252. Methods of Destroying the Wild Oat.—As the wild oat is propagated entirely from the seed, all methods for destroying it must depend for success upon preventing the plant from seeding, or, in other words, upon killing the plant before it has time to mature its seed. With this end in view, therefore, the following observations are made:

Fig. 14. Wild Oat.

(1) Sow the infested field with barley, and cut the crop on the green side. Then grind the grain before feeding it; or, which is even better, run it through a cutting-box and steam it before feeding it. In the next year, let the field be devoted to a hoed crop.

(2) Or, devote the field to a crop of rye, grown for soiling purposes; then follow with a crop of rape, sown in drills.

(3) If the infested field be in sod, break it up about the end of June, and work its surface well until the time for sowing winter wheat upon it. Then sow grass seed with the wheat. When the time for breaking the sod comes round again, repeat the process, if necessary. This method is well suited to clay lands, and on them proves very efficacious.

253. Couch-Grass.—Couch-grass is known also by a number of other names, as quack-grass, quitch-grass, twitch-grass, and dog-grass. It is a perennial plant, with long, creeping rootstocks, which quickly fill and take possession of the soil. Its leaves, near the

Fig. 15. Couch-grass

ground, resemble those of timothy. Its stems are from one to three feet high, and they bear at the end a slender spike, from two to several inches long. The feeding value of couch-grass is considerable, but it is looked upon as a great pest, since it can be dislodged only with great difficulty.

254. Methods of Destroying Couch-Grass.--The following methods for destroying couch-grass have been found efficacious:

(1) About the 1st of June, plow deeply the infested field, and sow thickly with buckwheat, which crop tends to smother the weed. When the buckwheat is in blossom, plow it under and sow thickly with buckwheat again. If the couch-grass is then not all destroyed, let the next season's crop be a hoed crop.

(2) Let the infested field be devoted to a heavy pea crop, since this crop also tends to smother the weed. Then let next season's crop be a hoed crop, well cared for. But it must be remembered, however, that cultivation in wet weather encourages couch-grass to grow.

255. Rag-weed.— Rag-weed is an annual plant, with a slender and much branched stem. Its leaves have very jagged

edges, from which fact the plant derives its name. Rag-weed is late in its habits of growth, and it is most to be met with in grain and hay stubbles. Hence, its seed is often found in clover seed. Moreover, being hard and indigestible, it is preserved in the excrement of animals; and, being unaffected by water, it is carried from one place to another by running streams.

256. Methods of Destroying Rag-weed.—Experience has shown the following methods to be efficacious:

Fig. 16. Ragweed.

(1) If the infested field be in stubble, plow it under as early as possible, so as to destroy the plants before the seeds have time to open.

(2) If the infested field be in meadow, and the rag-weed plants be numerous, give the field two mowings, both, however, before the time for the ripening of the seed; and let the mowings be made close to the surface. This precaution is necessary, since, the seeds of the rag-weed being formed low down on its stem, were the mowing not close to the surface, they might be left undisturbed. If the plants are not numerous, the second mowing may be dispensed with, and the plants be removed by hand.

(3) Devote the infested field to a hoed crop, making thorough work of the autumn cultivation.

257. Blue-weed.—Blue-weed is a biennial plant which rears several stems from a single stock, and produces beautiful blue flowers that blossom from June to August. Its seed often remains undisturbed till winter, when, being dislodged by the wind, it is carried long distances over the frozen ground or crusted snow.

258. Methods of Destroying Blue-weed.—The following observations are offered as based on experience:

(1) In the field, blue-weed cannot stand before the thorough cultivation necessary for a summer-fallow or a hoed crop. These, therefore, are the remedies for it there.

Fig. 17.   Blue-weed.

(2) But in fence corners, or on the road side, it must be destroyed with the spud. The stock of the weed should be cut below the crown before the seeds are formed. Mowing (by which the plant is necessarily cut *above* the crown) only induces it to form new branches, and thus become a worse pest than before.

259. The Ox-Eye Daisy.—The ox-eye daisy is a perennial plant, bearing beautiful star-like white flowers, which blossom in June. But it is distasteful to live stock, and since, if it be unmolested, it soon takes possession of the soil in which it is found, it must be considered a most troublesome weed, more especially in meadow pastures.

260. Methods of Destroying the Ox-Eye Daisy.—

The following observations are offered as based on experience:

(1) When the infested field is in sod, turn it under and devote it to a corn crop. Or (at any time in the rotation) have recourse to a hoed crop.

(2) Resort to a bare fallow. This will destroy all the plants then living. The few seeds that may escape and germinate subsequently, must, when they appear, be removed by the spud, as described in (3) below.

(3) When the above methods are inapplicable, resort to the spud, running it under the root a short distance below the surface.

Fig. 18.
Ox-Eye Daisy.

261. The Burdock.—

The burdock is a perennial plant, with great rhubarb-like leaves, and large burs filled with seeds. Its seed is disseminated by falling to the ground over which it is blown by the wind, or by the burs adhering to animals, by which they are carried from one place to another.

262. Methods of Destroying the Burdock.—

The following observations are offered as based on experience:

(1) Like the blue-weed, the burdock also cannot stand before the cultivation necessary for either a summer-fallow or a hoed crop.

(2) But if it is found in bye-places, it is destroyed by being cut with a spade below the crown, before it has had a chance to form seed. Two or three years of this treatment will eradicate it utterly.

263. Pigeon-weed.—

Pigeon weed, or red root, is an annual plant, with a branching disposition. It has a red root, and from this it derives one of its names. Its seeds are of great vitality, and as these ripen in June, the plant is most troublesome in wheat, rye, meadow land, and pasture.

264. Methods of Destroying Pigeon-weed.—

The following observations are offered as based on experience:

(1) For the fields that are infested let winter wheat and rye,

for a time, be omitted from the rotation. If these crops cannot be omitted, then the plants must be pulled out by hand.

(2) When the infested fields are in hay, or in pasture, let the plants be pulled by hand out of them also.

(3) But whenever practicable, resort to a summer-fallow, or to hoed crops.

CHAPTER XI.

Diseases of Crops.

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265. Causes of Most Crop Diseases.—Most diseases of crops are caused by plants of a very low order, called *fungi*; such, for example, as the blue-mould on cheese or bacon. Nearly all such plants are extremely small; and they do not possess roots, stems, or leaves, in the ordinary sense. Hence, most of them are dependent upon other plants of a higher order for their nourishment. They have no flowers; and, instead of seed, they produce very small bodies called *spores*. These spores vary much in size and shape; but in most instances they are so very small that millions upon millions of them float unseen in the atmosphere.

Some of these fungi grow upon one class of plants, and others upon another class. Moisture and warmth are necessary for their growth; and they usually grow on the leaves of plants, but sometimes also on the stems. So, when the air is moist and warm, and any of these very small, invisible spores, floating in the atmosphere, come into contact with the leaves of the right kind of plant, they stick to them and soon begin to grow, by sending out each a certain number of thread-like bodies, which are sometimes called spawn. These threads penetrate the tissue of the plants attacked; and feeding upon their juices they multiply and spread very rapidly. They often enter by the pores, or openings, on the under-side of leaves; and, as they grow, they form vast numbers of new spores, which they throw out into the atmosphere.

266. Conditions Favorable to Disease.—These are warmth and moisture, rankness of growth, and a weak or sickly condition of crops. Health, even in plants, is a matter-of much importance; for as a robust, healthy man is most likely to resist the infection of animal diseases, so also a strong, vigorous plant, in a natural condition, can best withstand the attacks of parasitic fungi. Ill-health in plants is often caused by lack of proper nourishment, or by stagnant water in the soil; also, when the land is too heavily manured, the crops which grow on it, being overcharged with sap, are apt to be soft, tender, and liable to disease.

267. Rust.—The disease of wheat, oats, barley, etc., commonly called "rust," is one of the best known, most widely-spread, and most troublesome of all plant diseases. So far as
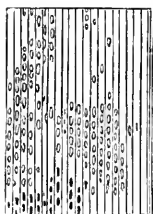
Fig. 19.—Piece of wheat leaf attacked by rust, enlarged to 3 times its natural size, and showing a few specks of black rust at bottom left-hand corner.

we know at present, there are two varieties of this disease, called spring rust and summer rust; and each is caused by a very small fungus, the spores of which float unseen in the atmosphere. Not only are there two varieties, but each variety has two distinct stages. In the first stage, or earlier part of the season, each variety produces reddish-colored spores, or *common rust;* and in the second or later stage, each produces dark-brown or black spores, called *black rust,* or *mildew,* such as is often seen on oats and on stubble after harvest. These black spores live through the winter, and carry the disease into the next season.

When the weather is damp and warm, or sultry, and the red spores spoken of above come into contact with wheat, barley, etc., they stick to the plants and begin to grow by sending out each one or two very fine thread-like bodies. These threads penetrate both the leaves and the stems, entering the leaves apparently from either side; and when once in the tissue of a plant, they feed on its juices and multiply with great rapidity, forming a close network and producing new spores, which burst out into

the atmosphere, as shown in Figure 20. The growth of these fungi in wheat, barley, etc., is so rapid and vigorous that they soon split the straw, after which the disease spreads so quickly that whole fields of grain are often destroyed in a few days.

Rain and sudden changes of temperature, accompanied by close, warm weather, are specially favorable to the growth of rust fungi. Over-richness of soil also,
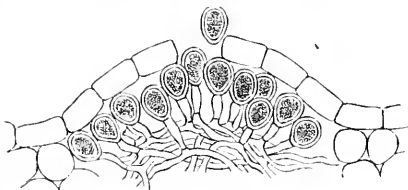

Fig. 20.—Section through a pustule of rust, enlarged to 200 times its natural size, and showing the thread-like bodies and spores.

caused by too liberal manuring, tends to produce in plants a soft, loose growth which exposes them to the disease; and late sown crops, especially on low-lying undrained land, are most subject to attack.

268. Remedies for Rust.—There is no remedy for rust; and when the attack is serious, the sooner the crop is cut the better. Every day it stands after a bad attack, only lessens its value. The best preventives of rust are thorough underdraining, early sowing, and the selection of seed from varieties which have proved themselves as nearly rust-proof as possible.

269. Smut.—This is another well-known disease which attacks wheat, barley, oats, and some other crops. It also is caused by parasitic fungi, the spores of which germinate, not in the atmosphere, but in the soil. There are, moreover, two varieties of this disease, commonly known as *hard smut* (or bunt), and *loose smut*.

Smut spores do not grow while they are dry, as when stored with seed wheat; but when carried with it into the damp soil, they soon germinate. In germination they send out extremely fine thread-like bodies, which penetrate the young plant in the soil. These threads grow in the plant, and with it, till they at last reach the forming seed, when they produce millions upon millions of black spores that take the place of the floury substances which should fill the seed.

Fig. 21 represents a grain of *hard smut*. In this and similar cases, the substance of the grain is completely destroyed, and its place taken by a black powdery dust (smut spores) of an unpleasant smell. When the crop is threshed, this black powder sticks to the sound grains, and the smell injures the flour made from them. Hard smut does not destroy the ear enclosing the grain.
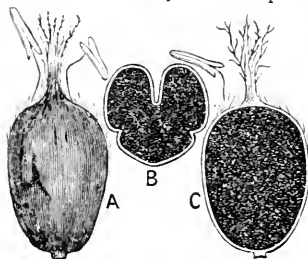

Fig. 21.

A.—Grain of wheat diseased with hard smut; enlarged to 5 times its natural size.
B.—A cross section of the same.
C.—A section made lengthwise through the grain.

Loose smut, as shown in Figure 22, begins at the bottom and works upwards, destroying both the ear and the grain. In this Province it does most damage to oats; but it is not so troublesome as hard smut, because it has no offensive smell to injure the sound grain, or the meal and flour made therefrom.

270. Remedies for Smut.—There is no remedy for smut, any more than for rust; but there are several preventives: (1) The use of seed which is as free from smut as possible; (2) a rotation of crops, which allows the smut spores added to the soil by one crop to perish before another crop of the same kind is grown upon it; (3) the application of some weak poisonous solution to the seed, to remove or destroy the smut spores on the grain, and by sticking to it, to prevent, as far as possible, the attack of spores in the soil after the seed is sown.

The solutions generally used for the destruction of smut spores on seed-grain are as follows: (1) A solution of *sulphate of copper*, or bluestone, say, in the proportion of 1 or 1½ pounds to a pailful of hot water; (2) *strong brine* (in which an egg will float), followed by an application of lime sufficient to make all the grains white; (3) *lye*, made by adding three or four gallons of boiling water to one gallon of good hard-wood ashes, and stirring for a short time; (4) a *soda solution* obtained by dissolving ordinary

washing-soda in water—about 2 pounds in a pailful. Of these, the first is regarded as the most powerful and certain preventive.

When any of the last three solutions are used, the seed should be soaked in it. With sulphate of copper, a good sprinkling, with thorough mixing of the seed, is all that is generally required. Where there is much smut soaking for a short time is no doubt necessary.

271. Other Diseases of Plants.—Not only rust and smut, but potato-rot, black-knot in plum trees, and various other forms of blight and disease in plants, are caused by attacks of fungus spores which float unseen in the atmosphere; and a short account of the most troublesome of these diseases, with the best remedies for each, would, no doubt, interest the readers of this primer; but want of space forbids even the briefest reference to any of them. We should like especially to speak of potato-rot and black-knot; but all we can say about them is, that the tops of potatoes affected with rot should be carefully gathered and burned, to prevent the spread of the disease; and, for the same reason, all trees on which the black-knot appears should be at once cut down and destroyed by fire.

CHAPTER XII.

Insects.

Fig. 22.—Head of wheat injured by loose smut.

272. Definition.—It is not necessary to give a formal definition of an insect. What an insect is can be best understood from a number of examples. Flies, crickets, and grasshoppers are insects. So also are bees, moths, butterflies, bugs, and

beetles. All of these are small animals, and they differ very much from one another; but they agree in several points, which distinguish them from other animals. Their bodies are all made up of a number of rings, as shown in figure 23; and, in their mature state, they have six legs. Some are wingless, but most of them have two pairs of wings; and they all breathe, not by means of their mouths, nor by nostrils, but by small air-holes, which are usually placed on their sides, though sometimes at the end of the tail, as in fly-maggots. When these breathing-pores are stopped up by any sticky substance, the insect dies for want of air; and a knowledge of this fact sometimes assists us in killing very troublesome pests.

273. Three Stages in the Life of Insects.—All animals change more or less in appearance as they grow; but insects undergo much greater and more sudden changes than other animals. Most insects, after being hatched from eggs or produced alive, exhibit three well-marked stages of development.
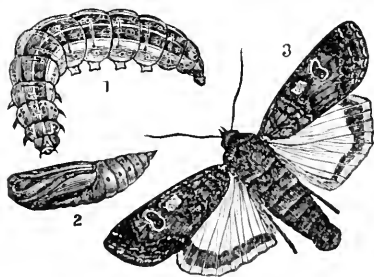

Fig. 23. Yellow Underwing Moth: (1) caterpillar; (2) pupa, or chrysalis; (3), imago, or perfect insect.

(1) The first stage is that of the grub, maggot, or caterpillar (scientifically called the *larva*, and in the plural *larvæ*). Many insects in this stage resemble worms. They have no wings, they feed greedily, and some of them grow very fast. Generally speaking, it is in this stage that insects do most harm to trees, fruit, and other crops.

(2) The second stage in the life of an insect is known as the *pupa*, or *chrysalis*. When the larva is full-grown, it usually rolls itself up in its skin, or weaves a case of silken threads (like that of the silk-worm), or makes a bed in the ground, and passes into a dormant or sleeping state, in which it is called the *pupa*

(Latin *pupa*, a girl or doll), from its supposed likeness to a baby rolled in bandages.   In this stage most insects are harmless.

(3) The third and last stage is that of the perfect insect, or *imago* (Latin for image), with all its feet, wings, and powers complete.   Some insects, however, have no wings, even in the perfect state.

Figure 23 shows the three stages of a well-known moth.

274. Classification of Insects.—There are several distinct classes of insects; but all we need say under this head is that insects are popularly divided into three groups: (1) *injurious insects*, like the wheat midge and the codling-moth (or apple-worm); (2) *beneficial insects*, such as ichneumon flies (which destroy many injurious insects), and bees, which gather honey and assist in fertilizing flowers; (3) *neutral insects*, which, so far as we know, do neither benefit nor injury to crops, fruits, and other things that we consider valuable.

275. Loss Caused by Insects.—The loss caused by insects in the Dominion of Canada is very great.   There is not a single plant which we grow that is not injured more or less by some grub, fly, or other form of insect life.   For many years, the loss to Ontario farmers from the wheat-midge alone amounted to millions of dollars annually; for a long time, the damage done by the pea-weevil throughout this Province could not have been less than $3,000,000 to $4,000,000 a year; and since 1872, the money paid by the farmers of Ontario for Paris green to destroy potato-beetles has averaged perhaps $220,000 a year, or about one-twentieth as much as their entire annual taxes for municipal and other purposes.   These are heavy losses, and the largeness of the amounts may surprise those who have not thought much about insects or their ravages ; but the figures are less than the reality.   In fact, we have no idea of the enormous loss caused every year, not only by the wheat-midge and the so-called "pea-bugs" and "potato-bugs," but by the codling-moth, plum-curculio, currant-worm, clover-midge, turnip-fly, Hessian-fly, cut-worms, cabbage-worms, and hundreds of other pests, which are always ready to destroy our crops.

In view of this great annual loss to farmers and fruit-growers, it is evidently desirable that boys and girls living on the farm should know something about insects. They should observe them closely, study their habits, get some knowledge of their life history, and learn, as far as possible, the best and cheapest means of destroying them, or preventing their ravages.

276. Insect Remedies. —Various means are used to prevent the ravages of insects:

(1) *The destruction of insect eggs and cocoons* wherever they are found; as on apple and plum twigs, in shrivelled leaves, in the crevices of bark on trees, amongst rubbish in fence corners, and elsewhere. With this object in view, fruit-growers often wash the trunks of their apple trees with soap-suds, lye, or lime.

(2) *Rotation of crops.* So long as the same kind of crop is grown on any piece of land, the insects which are in that place and feed upon that crop have a regular supply of food; but when there is an annual change, or rotation, in the kinds of crop, many young insects die every year for want of food.

(3) *Sowing at the right time.* In some places, it is necessary to have clover come into bloom at a certain time, in order to escape the midge; and, all over this Province, farmers sow their turnips so as to have them come up, if possible, just when the season for the turnip-fly is past.

(4) *Good seed, sufficient manure, and thorough cultivation.* These are to ensure strong, vigorous plants, which will grow in spite of slight, or even considerable, damage from insects or other causes.

(5) *Baits* and *traps* to catch the insects, and *barriers* to prevent them from reaching the plants. Pieces of cabbage leaves, for example, and bunches of fresh grass, wet with a solution of Paris green, are sometimes used as baits for cut-worms. Plum curculios, cucumber beetles, and other bugs and beetles, frequently hide under pieces of boards or chips during the day-time; and by laying shingles, or something of the kind, on the ground where they are likely to be, we are often enabled to entrap and destroy quite a number of them. **A** tarred rag

tied round the trunk of an apple tree, to catch wingless insects as they creep up to the leaves and fruit; pieces of paper placed in the ground around cabbage plants as they are set out, to keep the grubs away; bottomless boxes, with fine wire-gauze tops, placed over young cucumber plants, to ward off the beetles—all these are examples of barriers which may be used more or less by small gardeners and others who have only a few plants to look after: but none of the remedies under this head are of much use to farmers or gardeners who have large areas of crop to protect.

(6) *The consumption or destruction of worm-eaten fruit* as it falls in orchards. By this means, the worms in the fallen fruit are prevented from growing to maturity and producing a new crop of insects at a later stage the same season, or in the following year; and, for this reason, hogs are useful in an orchard.

(7) *Protection of beneficial insects and birds.* As already stated, some insects are useful and should be preserved, because they destroy injurious insects. Such are lady-bugs (called also lady-birds), tiger beetles, some ground beetles, and especially the wasp-like ichneumon flies, which prey upon cabbage-worms, army-worms, tent-caterpillars, potato-bugs, curculios, codling-moths, and many other troublesome insect pests. For the same reason, most of our birds should be protected and preserved from men and boys who are so thoughtless and cruel as to find pleasure in killing those innocent, beautiful creatures that add so much to our enjoyment every spring and summer. The king-bird, pewee, night-hawk, swallow, whip-poor-will, yellow warbler, American redstart, greenlet (red-eyed, warbling, and yellow-throated), cuckoo, blue-bird, white-bellied nuthatch, woodpecker (downy, golden-winged, hairy, and red-headed), thrush (tawny and brown), cat-bird, black-bird (crow and red-winged), mea-dow-lark, Baltimore oriole, indigo-bird, finch (grass and purple), black snow-bird, chewink, canary (American gold-finch), wren, chickadee, and other birds, devour vast numbers of worms, grubs, etc., and thus assist farmers and fruit-growers in protecting their crops from an endless variety of insect enemies.

(8) *Insecticides, or insect-killers.* The most valuable reme-

dies come under this head; and of these the cheapest, best, and easiest to apply are Paris green, London purple, kerosene emulsion, and hellebore.

277. Insecticides, and Their Application.—(1) *Paris green* is a compound of arsenic, and may be applied either dry or wet. If dry, it should be well-mixed with some fine powder, as land-plaster, air-slaked lime, flour, road-dust, or finely-sifted wood-ashes, in the proportion of one part of the poison (Paris green) to varying quantities of the powder, all the way from 50 to 100 parts. Lime and plaster are generally considered the best substances to mix it with, but any of the others are quite satisfactory. The mixing should be done very *thoroughly;* and, in the case of potato "bugs," cucumber beetles, etc., it may be applied by enclosing the mixture in a thin muslin bag and shaking it over the plants. In the wet mixture, which is best for fruit and shade trees, use one ounce of Paris green in from 9 to 12 gallons of water, and keep it *well stirred* while it is being applied. To kill the codling-moth (figures 24, 25, and 26), canker-worm, tent-caterpillar, and other insects, on apple-trees, for example, it should be applied *just after,* but not before *the blossoms* of the latest blooming varieties *have*

Fig. 24.—The Codling Moth (perfect insect of apple-worm).

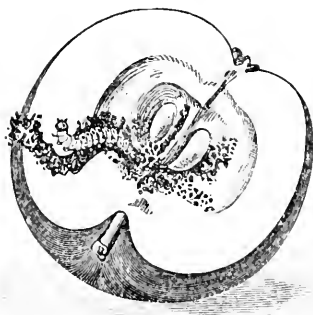
Fig. 25.—Young apple-worm working in towards the core.

Fig. 26. Worm of Codling Moth in the matured apple.

fallen. At that time, while the little apples are nearly all pointing upwards, the trees should be thoroughly sprayed by a force-

pump, or large syringe; and if heavy rains fall soon after, there should be a second application two or three weeks after the first.

(2) *London purple*, another substance containing arsenic, is now used a good deal by fruit-growers instead of Paris green. It costs about half the price, serves the same purpose, may be used in the same proportions, and applied in the same way.

(3) *Kerosene emulsion*. This is a mixture of soap, coal oil, and water, which is very cheap and very useful for killing plant lice, and various kinds of bugs, cabbage-worms, caterpillars, slugs, etc. It is made by mixing one quart of soft soap, or dissolving half a pound of hard soap, in from one to two gallons of boiling water, then adding one pint of coal oil, and stirring forcibly, by means of a syringe or force-pump, till it is permanently mixed, that is, till the oil is thoroughly incorporated with the water and soap, and will not rise to the top when the liquid is allowed to stand for some time. Before using, add about 14 pints of water, mix thoroughly, and apply with a syringe or force-pump.

(4) *Hellebore*, one part mixed with five to ten parts of flour, and dusted on the plants through a muslin bag, or through a piece of muslin held or tied over the mouth of a tumbler, is very useful for killing currant, raspberry, and strawberry worms. It may also be used with water, one ounce in two or three gallons, and applied with a syringe.

There are many other valuable insect remedies, but want space prevents us from going further under this head.

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CHAPTER XIII.

Outlines of the Principles of Feeding.*

[*To the Teacher:* The subject of this chapter is of the greatest importance to the farmer, but as it is naturally more difficult than the subjects treated of in the other chapters, it is impossible to present it very simply. To treat it briefly would be only to make its difficulty greater. It has been thought best, therefore, to present it with some detail, so that any diligent pupil can master it if he choose. *But in the first reading of the book, the parts printed in finer type had better be omitted.* Nevertheless, it should be impressed on every pupil that there is nothing in the whole chapter but what he ought to know, if he wishes to understand the principles of stock-feeding thoroughly.]

278. What Those Engaged in Feeding Should Know.—The feeding of animals can be more intelligently and effectively performed when those engaged in it have a general knowledge of (1) the construction of the animal body, and the functions discharged by the principal vital organs, and the other vital processes concerned in nutrition and animal development; (2) the composition of the animal body; and (3) the composition of the various foods in common use, and the relation which their constituents bear to each other and to the constituents of the animal body which they are intended to support and develop.

THE ANIMAL BODY: ITS CONSTRUCTION.

279. The Construction of the Animal Body.—The animal body consists essentially of (1) a skeleton or framework of *bones;* (2) fleshy parts, or *muscles,* which, for the most part, are attached to the bones, and by their action bring about the various movements of the body; (3) various *vital organs,* as the *stomach,* the *heart,* the *lungs,* the *liver,* the *pancreas,* the *kidneys,* which have special duties to perform, each essential to life; (4) the *arteries* and *veins,* a system of tubes leading from the heart and to the heart, and ramifying throughout the whole body; (5) the *connective tissue,* a general name given to the substance which

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*The author desires to acknowledge his indebtedness in this chapter to Professor Armsby, whose admirable work, "A Manual of Cattle-Feeding," may be regarded as authoritative.

ensheathes the bones, the muscles, the vital organs, and almost every other part of the body, and serves to join them together (where it hardens and forms the connection between bone and bone, or between muscle and bone, it is called *ligament* or *tendon*); (6) the *brain*, the seat of intelligence and will; (7) the *nerves*, by which sensations are carried to the brain, and by which also the commands of the will are conveyed to the muscles; (8) the *sensory organs*, that is, the organs of *sight, hearing, smell*, and *taste*; (9) the *capillary system*, that is, the system of minute vessels or canals, called the *capillaries*, connecting the arteries and veins, and forming an intricate network which pervades the whole organism (except a few parts, like the hair, the teeth, and the hoofs); (10) the *blood*, which fills the heart and all the passages leading from and to the heart; (11) *fatty matter*, which is stored up in various parts of the body, and which, though it is not essential to life, is used to support life when the due supply of food is lessened or cut off; and (12) the *integuments*, or "covering parts" of the body, that is, the skin, hair, wool, horns, hoofs, etc., found on the outside.*

280. The Bones.—The bones form the framework of the body. They determine the general outline of the body, and by their strength and rigidity enable it to sustain its own weight and to move itself from place to place; also to sustain and move such burdens as may be put upon it. The bones consist of two kinds of matter: (1) an *earthy* or *mineral matter*, forming about two-thirds of the whole bony structure (when bones are burnt, this is the part which remains); (2) an essentially *animal matter* (when bones are burnt, this is the part which disappears). The mineral matter consists principally of phosphate of lime, that is, phosphoric acid and lime (see section 97); but it contains also carbonate of lime, potash, and other substances. The animal matter yields on boiling a jelly-like substance, called "gelatine." The function of the mineral matter is to give strength and firmness to the bony substance. The function of the animal matter is to bind the particles of the earthy matter together, and to give toughness and elasticity to the bony substance. The bones of young animals are generally weak from lack of earthy matter, although for the same reason they are flexible, and thus not easily broken; contrariwise, from lack of animal matter, the bones of aged animals are deficient in toughness, and thus liable to fracture.

The bony structure is not altogether made up of hard substance, even in

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*In this account of the animal body, the *lymphatic system* has been purposely omitted, as not essential to the subject of the chapter.

the healthy adult animal. Besides the hard bone, there is a good deal of bony substance which is naturally more or less soft: this is called *cartilage.* Cartilage is frequently found on the ends of bones; that is, at the joints where they play or move upon one another.

As mentioned in the previous section, bones are held together by *ligaments;* while the muscles (see next section) are attached to the bones by *tendons.*

281. The Muscles.—The muscles of the body constitute its fleshy part. Each muscle consists of a multitude of minute fibres bound together into little bundles, while these bundles are again bound together to form the whole. But this binding is effected in numberless ways, so that muscles are of very many shapes. The muscles, in their turn, are attached by their ends to the various parts of the body, as the bones, and such organs as the eye-balls, the tongue, etc. Muscular fibre, when excited by nervous stimulus, contracts, and in contracting increases in thickness. Hence, when a muscle receives a certain nervous stimulus from the brain, its fibres all contract at once; in other words, the muscle shortens, its two ends approach towards one another, and those parts of the body to which the ends are attached (unless withheld by other muscles) must also approach one another. It is thus seen how the muscles, by reason of their contractile power, when under the influence of nervous stimulus, keep the bones balanced and the body in equilibrium, or else move the bones from one position to another, and so move the body in part or in whole from one position to another.

The muscles are oftentimes *not directly* attached to the bones with which they are connected. The connection is frequently made by the means of cord-like substances called *sinews* or *tendons.* For example, in the human body the muscles that close the fingers upon the palm of the hand and open them again are situated in the fore-arm some distance from the hand—the connection being made by tendons that pass up in front of the wrist.

282. The Vital Organs.—The *"vital organs"* is the name applied generally to those organs of the animal body which seem to be most essential to life, viz., the *stomach,* the *heart,* the *lungs,* the *liver,* the *pancreas,* the *kidneys;* although perhaps, speaking accurately, there is no organ of the body which is not essential to health, and therefore, in some degree, to life. Of the organs mentioned above, the heart and the lungs are, in a manner, the most important organs; for life cannot exist at all if their action be stopped, even for a very short time.

283. The Alimentary Canal.—The "alimentary canal" is the name given to the passage through the body, commencing at the mouth, by which the food (or crude "aliment") enters the body, and in which it is more or less prepared for being assimilated by the body; and by which those parts of it which are not retained by the body are finally ejected. It consists essentially of (1) the mouth; (2) the gullet; (3) the stomach; (4) the small intestine; (5) the large intestine. Of these, the stomach is the most important part, since it is in the stomach that the work of preparing the food for assimilation is principally effected. The passage through the body is complete and unobstructed; hence the fitness of the name "canal."

284. The Mouth.—The mouth is too familiar an organ to need description. In man and in domestic animals (but not in fowls or other birds) it is furnished with *teeth*, that is, instruments for seizing and separating the food, and dividing it into small parts.

285. Functions of the Mouth.—The process of dividing the food by the teeth is called *chewing* or *mastication*, and its purpose is to make the food more soluble and more easily acted upon by the fluids of the stomach. While in the mouth, also, the food is more or less mixed with a fluid called the *saliva*, which is secreted by certain glands that open into the mouth. The saliva moistens and softens the food, and thus assists in making it suitable for swallowing. It also partially dissolves it, and acts upon it chemically, and thus begins the work of preparation which the stomach and small intestine afterward effect more completely.

The food, on leaving the mouth, passes into the stomach through the *gullet* or *œsophagus*.

286. The Stomach.—The stomach, in domestic animals which do not chew the cud (as the horse and the pig), and also in man, is a large sac or pouch formed of several coats, the inner one of which is much gathered into folds. The walls of the stomach are largely composed of muscular fibres which, by their contraction and relaxation, cause the stomach to roll about, and, so to speak, "churn" its contents. (This movement of the stomach, like most other movements of the vital organs, is made independently of the will, and is thus said to be *involuntary*). The inner lining of the stomach is furnished with an infinite number of glands, which, when excited by the presence of food, exude into the stomach a thin acid fluid called the *gastric juice*.

287. Functions of the Stomach.—When the food passes into the stomach, it is subjected to the rolling or churning process referred to in the preceding section. At the same time, it is mixed with the gastric juice. The gastric juice contains two important ingredients. The first is *hydrochloric acid*, a chemical compound consisting of the elements hydrogen and chlorine (see section 17 (2)). The second is *pepsin*. These two substances, in conjunction with the churning process, act chemically upon the food and convert it into a more or less fluid mass (of about the consistency of pea-soup) called *chyme*.

288. Digestion.—The food is useless to the animal body unless it can be assimilated. It cannot be assimilated unless it is taken into the blood. It cannot be taken into the blood until it is prepared for that purpose. When the food is properly prepared for assimilation with the blood, it is said to be *digested*, and the process of preparation is called *digestion*. Some of the food is sufficiently digested by the time it is ready to leave the stomach; and the stomach walls are fitted with little blood-vessels which take up some of this digested food and carry it off. But the greater part of the food is only partially digested in the stomach. It passes thence into the next part of the alimentary canal, called the *small intestine*.

289. The Small Intestine.—The small intestine is a muscular tube of considerable length leading from the stomach. Its length varies in different animals, being, for example, comparatively much longer in the ox than in the horse, and in the sheep than in the hog. On account of its length, it must of necessity be much folded and bended on itself. Not far from where it leaves the stomach, it is entered (through a common opening) by two ducts, or small tubes, which lead, the one from the liver, the other from the pancreas. Like every other muscular part of the body, the small intestine is furnished with a great number of minute blood-vessels. Attached to it also are very many other small vessels which open out from it, and by numberless joinings finally all unite in one duct, or tube, which leads into a great blood-vessel that enters the heart. These are called the *lacteals*, or *lacteal vessels*.

290. Function of the Small Intestine.—The partially digested food or chyme is forced from the stomach into the small intestine. This is effected by the contraction of the stomach walls. It is then propelled along the intestine by successive worm-like contractions of the intestine, the wall of which narrows in diameter behind the food as it passes along. As the food passes the common aperture of the duct leading from the liver and the pancreas (see last section), it forces out and becomes mixed with a secretion from the liver called the *bile*, and another from the pancreas called the *pancreatic juice*. These secretions produce certain changes upon the chyme, and convert it into a milky fluid substance called *chyle*.

Chyle is the food completely digested and ready for absorption into the blood. A great part of the chyle is taken up by the minute blood-vessels[*] (mentioned in section 289) which belong to the intestine, and in this way passes directly into the blood. But perhaps an equal part does not thus enter the blood directly. Instead of this, it is taken up by the lacteals (described in the preceding section), and is conveyed by them (and the duct into which they all finally enter) into a great blood-vessel leading to the heart.

291. The Undigested Food.—Not all the food which is eaten is thus absorbed into the blood. Animals differ much in their capacities for digestion; and foods differ much in their digestibility. Moreover, some of the food that is digested may escape absorption. However, whatever is not absorbed into the blood is useless to the animal, and so may be considered indigestible. By more worm-like contractions, the indigestible part is propelled from the small intestine into the large intestine, and so onward, until it is finally ejected from the body.

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[*]These blood-vessels are the *capillaries and veins* (see sections 296 and 297) *of the intestines*; they all finally unite into one vessel, called the *portal vein*, which goes to the liver. In the liver, the contents of the portal vein are united with the blood supplied to the liver directly; the fluids, thus united, are carried away from the liver again by a vessel called the *hepatic vein*, and are finally conveyed to the heart (see section 294).

292. Rumination.—Animals that "chew the cud" (as, for example, the cow and the sheep), instead of the simple sac or pouch which constitutes the stomach of other domestic animals, and also of man, possess a *compound stomach.* This compound stomach consists of four divisions, the first one of which is the largest, and is called the "paunch." In the case of animals so furnished, the food is slightly chewed, and then taken, for the most part, into the paunch, but partly also into the second division. In these divisions of the stomach a portion of the food is dissolved, and passes directly through the other divisions into the small intestine. But the undissolved substances are returned, a portion at a time, to the mouth, and there are thoroughly chewed and mixed with saliva. When reswallowed, the food passes directly to the third division of the stomach. The coat of this division is provided with many folds, and these, by their contractions, subject the food to a great deal of movement and rubbing together. Thence the food is passed on into the fourth stomach, or "rennet," where it is mixed with the gastric juice and subjected to the same action as in the simple stomach of other animals.

Animals that chew the cud are called "ruminants," and the process of chewing the cud is called "rumination." The compound stomach, and the power to ruminate or "chew the cud," are evidently devices of nature to enable the animal to digest and make use of large quantities of coarse and comparatively poor fodder, such as hay, straw, etc., and to ex·ract from it all the nutrient matter it may contain. Cattle and sheep, whose stomachs are compound, are thus able to live on much coarser fodder than horses or swine, whose stomachs are simple.

293. The Circulatory System.—The stomach and the other parts of the alimentary canal are the organs that convert the food into *aliment*, that is, *food ready to be assimilated by the body.* The assimilation is done in the blood, and the blood, thus renewed by the new material which the food has given to it, is distributed to every part, to be used for the rebuilding of wasted or used up tissue (see section 306), and for adding new tissue to the body. This distribution is effected by *the circulatory system,* which consists of a central organ, called the *heart,* and of vessels which lead out from the heart to every part of the body, called the *arteries,* and of somewhat similar vessels that lead from every part of the body back to the heart, called the *veins.*

294. The Heart.—The heart consists essentially of a double muscular sac, which, by its power of regular contraction and relaxation, forces the blood contained in it out through the arteries leading from it to every part of the body, and, at the same time, receives back the blood which is conveyed to it from every part of the body by the veins.

295. The Arteries.—The arteries are the vessels which carry the blood to every part of the body *from* the heart. On first leaving the heart there are but two arteries, though these afterwards subdivide innumerably. The artery from the left side of the heart (the *aorta*) carries the blood to every part of the body except the lungs (see section 299). The artery from the right side of the heart (the *pulmonary artery*) carries the blood to the lungs, and to the lungs only.

296. The Veins.—The veins are the vessels which bring the blood from every part of the body *back to* the heart. On entering the heart there are (practically speaking) but two veins, though innumerable smaller veins have previously united to form these two. The vein which enters the right side of the heart brings blood back to the heart from every part of the body except the lungs. The vein which enters the left side of the heart (the *pulmonary vein*) brings blood back to the heart from the lungs, and the lungs only.

297. The Capillaries.—The capillaries are exceedingly minute and very thin blood-vessels forming a network in every part of the body, and connecting the terminations of the arteries with the beginnings of the veins.

298. The Blood.—The blood is a fluid which fills the whole circulatory system. By the action of the heart it is kept in constant circulation. There may be said to be two sorts of blood, *arterial blood*, and *venous blood*. Arterial blood is so-called because it is found in all the arteries except those going to the lungs. It is bright-red in color. Venous blood is so-called because it is found in all the veins except those coming from the lungs. It is dark-red in color. The blood, as a whole, is all the while in a state of change. New substance is being constantly added to it from the food, and also from the air which is inhaled by the lungs; other new substance is also being constantly added to it by its absorption of worn out tissues of the body. On the other hand, substance is constantly leaving it to be deposited as permanent tissue in the body; and other substance is constantly leaving it to be excreted from the body altogether. This will be more fully explained in subsequent sections.

299. The Lungs.—The lungs are two large organs composed essentially of numberless air-cells and tubes, all enclosed in a sort of sac. The various air-cells and tubes of the lungs are joined together in innumerable ways, but finally they all unite in a single tube, called the *wind-pipe*, leading to the mouth. Interspersed with the air-cells of the lungs are innumerable capillaries and blood-vessels, forming an intricate network which connects the artery that comes from the heart to the lungs (the pulmonary artery) with the vein that goes from the lungs to the heart (the pulmonary vein).

300. Function of the Circulatory System.—Speaking generally

the circulation of the blood through the body is as follows: By the contraction of the left side of the heart the blood is forced into the aorta, and by the aorta and its branches it is carried into every part of the body except the lungs. Whilst in the arteries, the blood is of a bright-red color, and possesses, moreover, new substance gained from the food by means of the lacteals (see section 289), and a new supply of oxygen, gained from the air by means of the lungs (see section 301). But in its passage through the capillaries which join the arteries with the veins, the blood suffers a great change. The sides of the capillaries are very thin, and the blood in passing through them actually comes in contact with the tissues of the body. Part of its substance is here left behind to form new tissue, and the waste or used up tissue, thus replaced, is absorbed by the blood. But a large portion of this absorbed waste tissue also suffers a change. Its carbon unites with the oxygen of the blood to form carbonic acid gas (see section 7 (3)); its hydrogen unites with the oxygen of the blood to form water (see section 17 (2)); and other combinations occur. This breaking up of solid substance and formation of new compounds by reason of the presence of oxygen is called "oxidation." The products of the oxidation in this instance, namely, the carbonic acid gas, the water, and the remaining substance of the waste tissues, are carried off by the blood to be excreted or passed out of the body by the lungs, the kidneys, and the skin.

This union of the oxygen of the blood with the carbon and hydrogen of the waste tissue is precisely the same sort of chemical union which takes place in the combustion seen in an ordinary stove, or lamp, or candle, where the wood or coal, or oil, or tallow, unites with the oxygen of the air to form carbonic acid gas and water-vapor, and to produce heat. And in precisely the same manner the union of the oxygen of the blood with the carbon and hydrogen of the waste tissue results in the production of carbonic acid gas, water-vapor, and *heat*. In other words, a slow process of *burning* goes on in the animal body as the blood passes through the capillaries, a large portion of the used up tissue being *burnt* (that is, changed into carbonic acid gas and water-vapor), and warmth, or animal heat, also being produced.

At the same time, the color of the blood is changed, namely, from a bright-red to a dark-red. So that the blood in the veins differs from the blood in the arteries (1) in being of a dark-red color instead of a bright-red; (2) in being charged with waste tissue and having parted with its material for new tissue; and (3) in having gained carbonic acid, water-vapor, and other products of the oxidation, and having lost oxygen.

The blood, having entered the veins from the capillaries, is carried onwards to the heart, and finally enters the heart at its right side. And by the contraction of the right side of the heart, it is then sent to the lungs through the pulmonary artery. The blood, therefore, that enters the lungs is venous blood, containing a large excess of carbonic acid gas, and much water-vapor, and not having a sufficiency of oxygen.

301. Function of the Lungs.—The lungs are so placed in the body

Fig. 27. *Ideal view* of the circulatory system of the animal body, and of the lungs, liver, kidneys, small intestine, etc. (1) Heart, left side; (2) heart, right side; (3) aorta; (4) artery supplying the abdominal cavity and back part of the body; (5) capillaries; (6) vein from abdominal cavity and back part of body; (7) artery supplying fore-part of body and head; (8) capillaries; (9) vein from fore-part of body and head; (10) pulmonary artery; (11), (11) lungs; (12) pulmonary vein; (13) artery supplying small intestine branching into smaller blood-vessels and capillaries; (14), (14) the small intestine; (15) blood-vessels (capillaries and veins) carrying away blood and absorbed nutrients from the small intestine; (16) portal vein; (17) artery supplying blood to the liver; (18) liver; (19) vein carrying blood from the liver; (20) lacteals; (21) the duct which carries the nutrients absorbed by the lacteals (chyle) to a vein leading to the heart; (22) artery supplying blood to the kidneys; (23) kidneys; (24) vein carrying blood from the kidneys. [NOTE.—The arrows indicate the directions in which the blood, chyle, etc., move. Arterial blood is left unshaded. Venous blood is shown by the shading. The observer is supposed to be looking at the *front* or *under part* of the body. The student must remember that the diagram is only an *ideal representation*, and useful to show only in a *general way* the relative positions of the circulatory organs, etc., and the courses of the circulatory fluids. He should, if possible, observe the things here represented in the body, heart, lungs, etc., of a sheep or pig.]
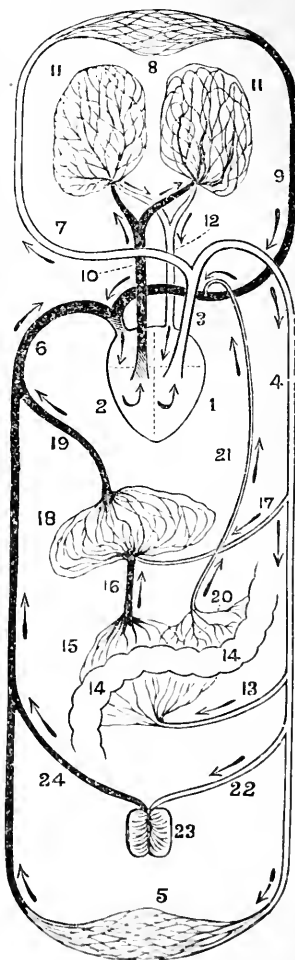
that by an involuntary action of the chest and other parts of the body they are continually made to expand and contract. By their expansion they cause air to come down the wind-pipe and enter their numerous cells. The walls of these cells, and also of the capillaries and little blood-vessels which are interspersed with them, are so thin that the air of the lungs practically comes into contact with the blood of these blood-vessels, and an interchange of gases takes place. The carbonic acid gas of the dark venous blood that has come from the heart passes into the air of the lungs, as also does much of the water-vapor, while the oxygen of the air of the lungs passes into the blood in the blood-vessels. Thus the air in the lungs gains in carbonic acid gas and water-vapor, and loses in oxygen; and the blood in the blood-vessels of the lungs gains in oxygen, and loses in carbonic acid gas and water-vapor; at the same time, the blood loses its dark-red color and becomes bright-red again. The lungs now contract, and their contraction forces out a large portion of the air that is within, which is therefore air that has carbonic acid gas and water-vapor in excess. At the same time, the blood, thus charged with oxygen and brightened in color, passes on to the heart, entering it on its left side.

It will be seen from what has been stated that while the blood is the vehicle by which all new substance is conveyed to those parts of the body where it is needed, it is also the stream into which are poured, as into a sewer, all those waste substances of the body which are no longer required, and which must be got rid of.

302. The Excretory Organs.—We have seen (see section 290) how the nutrient matter which is supplied by the food is made a part of the blood, and also (in section 300) how it is carried by the circulatory system to every part of the body, to take the place of tissue that is worn out, or to build up new tissue. Again, we have seen in the last two sections how the oxygen which is gained from the air is taken into the blood, and how, by means of the circulatory system, it is conveyed to every part of the body for the purpose of oxidizing (that is, *burning*) the worn out tissues of the body. We have also seen how some of the products of this combustion (namely, carbonic acid gas and water-vapor) are brought to the lungs, and are by them expired into the outside air. But the lungs do not get rid of all the carbonic acid of the blood, or of all the water that needs to be excreted; and, moreover, there are many other impurities of the blood (some the products of oxidation, and some perhaps not), gathered up by it in its circulation through every part of the body, which must also be got rid of. Summing up, however, it may be stated that the principal impurities of the blood which must be got rid of in some way or other are these three: (1) *carbonic acid gas;* (2) *water;* (3) *urea,* the characteristic ingredient of urine. Of course the other impurities are to be got rid of also, but they are all excreted by the same means that are necessary to excrete these three.

The processes by which the impurities with which the blood becomes charged are got rid of, are too intricate to be described fully in an elementary

text-book like this. But, as has been said, the three instruments for getting rid of them are the lungs, the skin, and the kidneys. As we have seen in the last section, *the lungs* rid the blood of much of its carbonic acid gas, and also of a good deal of its water which they exhale from the body in the form of water-vapor. Secondly, through the *pores of the skin* a constant perspiration or sweating process goes on, by which the blood gets rid of water principally, but also of some carbonic acid gas. Thirdly, the *kidneys* are instrumental in removing from the blood and passing out of the body all its urea, and a great portion of its water as well. [NOTE.—We have not, of course, accounted for all the products of the excretory organs. The kidneys are very instrumental in excreting, along with water and urea, various saline substances. The skin also excretes various saline substances, as witness the salty taste of the perspiration of the human body. The lungs exhale, along with their water-vapor and carbonic acid gas, a good deal of worn out tissue in very finely divided particles. But the excreted products we have named are the principal ones].

The kidneys are two large glands situated at the back of the lower part of the abdominal cavity (that is, the cavity that holds the stomach, intestines, etc.). Through them a constant current of blood passes, brought to them by a large artery, and taken away by a large vein. In its passage through the kidneys, the blood is freed from the impurities mentioned above as being those which the kidneys secrete, viz., water, urea, and various saline substances. These impurities, as fast as they are secreted by the kidneys, are deposited in a sac called the bladder, by which, at intervals, they are ejected from the body.

The normal or proper action of the kidneys is of the utmost consequence to the healthy working of the animal organism; but scarcely less so is the normal action of the skin; while the importance of a healthy state and proper action of the lungs is too well known to need any emphasis.

THE ANIMAL BODY: ITS COMPOSITION.

303. The Composition of the Animal Body.—The animal body may be roughly spoken of as consisting of (1) water; (2) dry matter. The relative proportion of these constituents varies with age. In new-born animals, water forms as much as 80 or 85 per cent. of the whole weight; in mature but not fattened animals, it forms about 50 or 60 per cent.; while in fattened animals, it forms sometimes not more than 35 per cent. Water is found in all the tissues of the body, the so-called solid parts as well as others.

304. The Dry Substance of the Animal Body.—The dry substance of the animal body is that which remains when all the water has been evaporated or expelled by heat. As seen in the previous section, it is

generally less than one-half the weight of the animal.   It consists of (1) *organic matter;* (2) *inorganic matter.*

"Organic matter" is the name applied generally to substances peculiar to living bodies, that is, to substances consisting of elements united into compounds found only in animals or plants (see also section 17 (4)).   The organic matter of the animal body is that which *disappears* when the body is burnt (with the exception, of course, of the water, which also disappears when the body is burnt).

"Inorganic matter" is the name applied generally to substances not peculiar to living bodies, that is, to substances consisting of elements united into compounds found not only in animals and plants, but also in other things as well.   Inorganic matter is often called "mineral matter."   The inorganic matter of the animal body is that which *remains* when the body is burnt.

305. The Inorganic Matter of the Animal Body.—The inorganic matter of the dry substance of the animal body is (as was said in last section) the *incombustible* or *non-volatile* part.   It is commonly called the *ash* (see also section 17 (3)).   In respect of quantity, it varies from about 2 to about 5 per cent. of the live weight.   The greater portion of the ash of animals (from about 50 to 75 per cent.) is found in the bones.

306. The Organic Matter of the Animal Body.—The organic matter of the animal body is the *combustible* part, or (as was said in section 304) that part (with the exception of the water) which disappears when the body is burnt.*   The *solid* organic substance of the animal body is known by the general name of *tissue.*

307. The Chemical Composition of the Animal Body.

—The chemical elements of the animal body are essentially the ten elementary substances which, in section 17 (2), were mentioned as being necessary to the growth of plants, namely, *carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, calcium, magnesium,* and *iron;* with *chlorine* and *sodium* (that is, the elements of common salt), *in addition.* And as in plants, so in animals, these elements do not exist simply, but are united into numberless compounds, both organic and inorganic.   And as in the case of plants (see section 17 (4)), so also with the substances of the animal body, it has been found convenient to speak of them as belonging to one or other of two classes, according as the chemical compounds of which

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*When a combustible body is burnt, the water which it contains disappears as vapor, very much as a great portion of its solid substance disappears as gas, but nevertheless the water does not burn.   It evaporates, or goes off in the form of vapor.

they are composed contain nitrogen, or do not contain it. Those substances therefore of the animal body which contain nitrogen are called *nitrogenous substances*, and those which do not contain it are called *non-nitrogenous substances*. Water, which is composed of hydrogen and oxygen (see section 17 (2)), is of course a non-nitrogenous substance; but in considering, for the purpose of acquiring knowledge respecting the laws of feeding, whether the substances of the animal body are nitrogenous or non-nitrogenous, it is usual to consider only the *dry portion*, and the water is therefore neglected; the reason being that water forms a considerable part of all digestible foods, and its lack in any particular food can be very easily supplied.

308. The Nitrogenous Substances.—The nitrogenous substances of the animal body consist mainly of three groups: (1) the *albuminoids;* (2) the *gelatinoids;* (3) the **horny matters**. These substances are all organic compounds.

309. The Non-Nitrogenous Substances.—The non-nitrogenous substances of the animal body are both organic and inorganic. Of the organic non-nitrogenous substances, *fat* is by far the most abundant. Of the inorganic non-nitrogenous substances, the various mineral compounds found in bone-ash (of which phosphate of lime is the chief: see section 97) are the most abundant. Besides these main non-nitrogenous substances, there are others; but they occur only in inconsiderable quantities, though of course they all are important to the animal economy. Of these, *sugar*, and certain *acids* and *salts*, are the chief.

The Nitrogenous Substances.

310. The Albuminoids.—Of the nitrogenous substances of the animal body, the albuminoids are by far the most important; and, in a sense, they are the most important of all the substances of the body. Their importance lies in the fact that "all the manifestations of animal life are dependent on them, and on the organs which are composed of them, and that, moreover, they furnish the material out of which the members of both the other groups of nitrogenous substances (that is, the gelatinoids and the horny matters) are formed." The albuminoids are found

under various manifestations in all the organs and fluids of the healthy body, except the urine, constituting the chief constituents of their composition. Nearly all the vital processes of the body have for their object the effecting of changes upon the form, location, or function, of its albuminoid material. Though of many diverse characteristics, the albuminoids have many characteristics in common, one of these being that, in composition, they all resemble the white of egg. And since the white of egg is known in science by its Latin name, "albumen," it is seen that it is from this resemblance they derive their name. The principal albuminoids of the animal body are: *albumin,* found in nearly all the fluids of the body (forming also the chief constituent of white of egg); *flesh-fibrin,* the chief constituent of muscular fibre; *blood-fibrin,* the essential constituent of the clotting part of blood; and *casein,* the constituent of milk which forms the basis of cheese. But, besides these, there are innumerable others.

A very general characteristic of the albuminoids is their tendency to *coagulate,* or *clot,* under the influence of heat, or by the action of some acid, or otherwise. Familiar examples of this are the coagulation of white of egg due to heat, the clotting of blood, and the formation of curd in milk by the presence of "rennet." But this coagulation is only a change of form. It is not accompanied by any change of condition.

311. The Gelatinoids. —The gelatinoids, the second group of the nitrogenous substances of the animal body, constitute almost the same proportion by weight as the albuminoids. They form the nitrogenous substance of the bones and cartilages, and they make up, besides, the larger part of the tendons, ligaments, connective tissue, and the skin. They derive their name from the fact that the parts of the body which contain them, when subjected to protracted boiling, furnish, on cooling, a jelly-like substance, commonly known as *gelatine.* As an illustration of this fact, it may be mentioned that it is from these parts that *glue* is obtained.

312. The Horny Matters. —The third group of the nitrogenous substances of the animal body are the horny matters. They differ very little in chemical composition from either the

albuminoids or the gelatinoids. They are found chiefly on the outer surface of the body, that is, in the epidermis or scarf-skin, and in such other coverings as the hair, the wool, the horns, the nails, hoofs, claws, feathers, etc.

As mentioned in section 310, both the gelatinoids and the horny matters of the animal body are formed out of the albuminoids in the natural processes of nutrition and growth. But, once formed, they cannot be changed back into albuminoids; neither are they, like the albuminoids, capable of nourishing the body as food.

313. Composition of the Nitrogenous Substances of the Animal Body.—Since the second and third groups of the nitrogenous substances in the animal body, that is, the gelatinoids and the horny matters, are formed either directly or indirectly out of the first group, it follows, therefore, that the chemical composition of all three groups is practically the same. Their constituent elements have been found to be carbon, hydrogen, oxygen, nitrogen, and sulphur. Of these elements, carbon is the most abundant, and sulphur the least. The nitrogen (which is the distinctive constituent) has been found to be of an almost constant proportion in the composition, viz., about 16 per cent., or $\frac{4}{25}$.

It should be remarked that the same chemical composition has been ascertained to hold with respect to the nitrogenous substances found in foods.

Hence, if the percentage of *nitrogen* in the dry organic substance of the animal body, or of a food, be known, the percentage of *nitrogenous organic substance* contained in the same can be easily calculated; for the latter will be obtained from the former by multiplying by $\frac{25}{4}$, or $6\frac{1}{4}$. This fact (though why it is so cannot be made very intelligible here) is of great importance in the science of feeding, and ought to be remembered by the pupil, who will frequently have occasion to use it when he comes to read more advanced works on the subject.

314. Importance of the Nitrogenous Substances of the Animal Body.—From what has been said in sections 310 to 312, it will be seen that the nitrogenous substances of the animal body are of the utmost importance. Not only do many vital processes depend on them, but they constitute also the greater portion of the material of the vital organs; the greater portion of the muscles, nerves, tendons, etc.; a large portion of the bony matter (that is, the combustible part); and almost all the integuments, that is, the covering parts, the skin, hair, wool, nails, hoofs, etc. Hence one of the main objects of the feeder should always be to see that his animals are supplied with foods

of such qualities, and in such quantities, as will be sufficient for the sustenance and development of the nitrogenous portions of the animal body, since these are so numerous and so important.

The Non-Nitrogenous Substances.

315. Fat.—Fat (see section 309) is the most abundant of the non-nitrogenous organic substances of the animal body. It is found in various parts of the body, in some places as minute particles, in others as special deposits of considerable quantity. From a feeder's point of view, the fat which is formed in the fleshy parts of the body, between the bundles of the muscular fibres, is perhaps the most important. Fat consists essentially of carbon, hydrogen, and oxygen. But in the fat tissue, and apparently (though, of course, not really) forming a part of its solid substance, is about from 5 to 25 per cent. of water. The proportion of fat in the animal body varies greatly; sometimes the proportion may be as much as 40 per cent.

316. Other Non-Nitrogenous Substances.—Of the other non-nitrogenous *organic* substances of the animal body, there are none existing in very considerable quantities. They are principally *sugar*, and certain substances resembling sugar, and various acids and juices not necessary to be described here. The *inorganic* substances of the animal body are *all* non-nitrogenous. They consist principally of the several components of bone-ash (carbonate of lime,* phosphate of lime, potash, etc.), and of certain salts, of which common salt is one.

FUNCTIONS OF THE FOOD.

317. The Food must first be Sufficient for Maintenance.—Upon the food which the animal consumes depends of course not only its maintenance, but also its ability to grow or develop flesh or fat, or to produce any useful product, or to work. *But, first of all, the food supply must be sufficient for maintenance.* This will be more clearly apprehended from the following consideration: We have seen that, as a result of the presence of oxygen in the blood, a constant oxidation of tissue is going on; that is, the already-formed tissue of the body is constantly being broken up, absorbed

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*Carbonate of lime is a compound of lime and carbonic acid ; phosphate of lime is a compound of lime and phosphoric acid. Phosphate of lime makes up about seven-eighths of the total quantity of bone-ash. Therefore since, for purposes of feeding, there is no need of taking account of the *carbonic acid*, the inorganic constituents of bone are often stated as being *lime*, *phosphoric acid*, *potash*, etc.

by the blood, and made to form new combinations with it; or, in other words, that worn-out material is constantly being abstracted from the body-tissue and made part of the blood. Moreover, a similar oxidation and formation of waste material is constantly going on with respect to new substance in the blood, fresh obtained from the food, and not yet organized into tissue. This constant oxidation of organized tissue and of new substance from the food, is a vital process essential to life; it is, as we shall see, the source of all the vital heat and energy of the body. Hence the material which is thus oxidized is also essential to life; that is, life cannot continue unless there be a requisite supply of it. This material, whether tissue already formed, or substance in the blood not yet organized, necessarily comes from the food. If the formation of new tissue goes on just as fast as the oxidation of the tissue already formed, then the body is neither wasting nor gaining—it is simply maintaining itself in equilibrium. But if the formation of new tissue does not keep pace with the oxidation of the tissue already formed, then it is evident that the body must be wasting—the material must be supplied for the oxidation to go on at a fairly constant rate, or else the vital processes will stop and life become extinct. And it is further evident that none of the food can be available for the production of new tissue as growth, or as the development of flesh or fat, or for any other purpose whatever, until what is needed to furnish the material for the necessary oxidation constantly going on is wholly supplied.

318. Disposition of the Food Required for Maintenance.—It will be seen from the preceding section that when an animal is maintaining itself in equilibrium, that is, when it is neither gaining nor losing flesh, the function of the digested food is simply to supply so much new tissue as will replace that which is necessarily oxidized and absorbed by the blood, and carried off as waste material by the excretory organs. Or, in other words, all the food consumed and digested is sooner or later oxidized in the blood, converted into carbonic acid gas, water, urea, or some other waste product, and excreted from the body by the lungs, skin, or kidneys.

319. What Constitutes a Proper Food Supply.—Animals are rarely fed for the sake of maintenance merely. They are intended to grow, or to develop fat or flesh, or to do work, in addition to maintaining their vital processes. But we have seen that the first function of the food is to maintain these vital processes in necessary and sufficient activity. Therefore it is evident that the food supplied to the animal (taking no account of what is of no use through not being digested) ought, first of all, to correspond in quantity and in composition to the quantity and composition of the substance passed out of the body by the excretory organs in healthy action; that is, that it should contain the elements of carbonic acid, water, urea, etc., just in the quantities and proportions in which these substances are found in the excreted products; otherwise, there would be waste; and that whatever else in the way of food is supplied, ought to be of a kind best suited to develop, without waste, such tissues as may be desired, as, for example, those for

growth, if it be a growing animal, or those deemed most suitable as components of meat, if it be a fattening animal

320. Disposition of the Nitrogen of the Food.—All the food taken into the body and digested is either retained in the body for the formation of tissue, or else it is excreted by the lungs, skin, and kidneys. All the worn-out and waste tissues of the body are also excreted by the same organs Therefore all the food taken into the body and digested, and not retained as permanent tissue, must pass out of the body by way of the lungs, the skin, or the kidneys. The excretory products of the lungs are, as we have seen, carbonic acid gas and water; of the skin, the excretory products are water, and some carbonic acid gas; and of the kidneys, the excretory products are water and urea. Carbonic acid gas is composed of carbon and oxygen; water is composed of hydrogen and oxygen; urea is composed of carbon, oxygen, hydrogen, and *nitrogen.* Urea, then, is the only one of these substances that contains nitrogen. These are all the substances excreted (see section 302), except some saline and other matters, which do not contain nitrogen. The kidneys, therefore, are the only organs to excrete nitrogen. It follows, then, that of all the nitrogen taken into the body (in the nitrogenous food consumed and *digested*), the whole of the excess, over and above what is retained for the repair of old nitrogenous tissue, or the formation of new nitrogenous tissue, must be excreted by the kidneys, and by them be passed out of the body. This fact is important; and though the reason for its importance cannot be explained here, yet upon it a great deal of the science of feeding is based, which the pupil will better understand when he is able to read more advanced text-books. [Note.—It must not be forgotten that the *solid* excrement of animals contains nitrogen also, since it rarely happens that all the nitrogenous food consumed by an animal is *digested* by it. Nitrogen is, in fact, one of the most important ingredients of solid manure, especially when the manure is obtained from well-fed animals.]

THE CONSTITUENTS OF THE FEEDING STUFFS.

321. Nutrients.—In feeding, the term *nutrient* is used to denote any single chemical compound which is capable of being assimilated by the body for the purpose of producing new tissue, either for new growth, or to replace that which is worn out. We have seen that the body is composed of (1) nitrogenous organic substance; (2) non-nitrogenous organic substance; (3) mineral substance. Hence, since a nutrient, in order to permit of easy assimilation, must in its composition be identical with the substances normally found in the body, the nutrients permit of classification very similar to the classification of the substances of the body. They are thus: (1) nitrogenous organic substances;

(2) non-nitrogenous organic substances; (3) mineral or inorganic substances. Albumin, or the essential constituent of white of egg (see section 310), is an example of a nitrogenous nutrient; fat, starch, sugar, are examples of non-nitrogenous nutrients; common salt and phosphate of lime are examples of mineral or inorganic nutrients. Nutrients are, however, very rarely found in a pure or unmixed state. Nitrogenous nutrients, non-nitrogenous nutrients, and mineral nutrients, are generally combined in one fodder, or feeding-stuff (see next section), as, for example, in any of the ordinary grains or grasses.

322. Fodders.—*Fodder*, or *feeding-stuff*, is the term used to denote any natural or artificial product which is used as food for animals. Fodders are naturally more or less complex in their composition, and therefore are likely to contain not only two or more nutrients intimately blended, but also substance which is quite indigestible and unfit for food altogether. It is the duty of the feeder to study the composition of his feeding-stuffs, and to know, as far as possible, of what sort of nutrients they are composed, so as to use them properly in his feeding. Some feeding-stuffs, as oil cake and cotton-seed cake, are (comparatively) largely nitrogenous in their composition; others, as corn, are largely non-nitrogenous. Practically, there are no feeding-stuffs that are wholly nitrogenous, or wholly non-nitrogenous, in their nature; and as both kinds of nutrients are needed to maintain the animal organism in a healthy condition, it is well that this is so. Some feeding-stuffs, as *hay*, for example, contain their nitrogenous and non-nitrogenous nutrients so properly balanced that they make suitable food without admixture with anything else. But such happy combinations are rare; and therefore, since the feeder cannot find them at his hand, he must construct them for himself.

323. Rations.—*Ration* is the term applied to a combination of feeding-stuffs chosen so as to contain their various nutrients in such balance that their nitrogenous and non-nitrogenous constituents are in the proper proportions to maintain healthy life *economically* (that is, *without unnecessary waste*), and to produce those results of development or of special

production (such as beef, milk, wool, etc.) which the feeder may desire. It should be said here that (with the exception of common salt) the *mineral* nutrients necessary to animal sustenance and development are usually present in sufficient quantities in any ordinary combination of feeding-stuffs. Hence these are rarely taken into consideration in the discussion of rations; and the question at any time is only in what proportions ought certain given feeding-stuffs to be combined in order to form a ration which shall have its *nitrogenous* and its *non-nitrogenous constituents* combined in proportions suitable to effect the purposes of the feeder.

324. Classification of Feeding-Stuffs.—Since substances are valuable as food only because of the nutrients which they contain, and since also all foods generally contain a sufficiency of the mineral nutrients (with the exception of common salt), it follows that foods may be roughly classified as *nitrogenous*, or *non-nitrogenous*, according as their organic nutrients are more largely of the one sort or of the other.

325. A More Minute Classification of the Feeding-Stuffs.—As all animals which the stockman has to deal with, feed, for the most part, on *vegetable* foods, it follows that, in considering a *more minute* classification of foods, we have mainly to think of *plant foods*. Now, in section 17 (4) (*a*), it was seen that the principal nitrogenous constituents of plants are the *albuminoids*; as legumin, the nitrogenous constituent of peas, beans, and clover, and gluten, the nitrogenous constituent of wheat. And in section 17 (4) (*b*), it was seen that the principal non-nitrogenous constituents of plants are cellulose, starch, sugar, gum, fat, oil, and the various vegetable acids. Of these, cellulose, starch, sugar, gum, being composed principally of carbon, hydrogen and oxygen, are called the *carbo-hydrates*. The fat and oil are generally considered together as *fat*. The other non-nitrogenous constituents, such as the vegetable acids, though they affect the taste of foods and influence digestion, play much the same part in the work of nutrition as the carbo-hydrates, and therefore may be reckoned in with them. So that it follows that the non-nitrogenous constituents of plant foods may be considered as being either *carbo-hydrates*, or *fats*. And as it often happens that the cellulose of plants, when they are matured sufficiently to be used as food, becomes hardened into a more or less indigestible fibrous condition, it is usual to exclude this difficultly digestible part from the remaining carbo-hydrates, and to place it in a class by itself as *crude fibre*.* Then there is the *ash*, or

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*The ruminating animals, the cow, the sheep, etc., are able to digest a considerable portion of this crude fibre; the horse is much less able to digest it; and the hog is able to digest but little of it.

mineral part, the part that remains when the plant is consumed by fire. And it must not be forgotten that all this applies only to the *dry substance* of foods, and that oftentimes a large percentage of the apparently solid substance is *water*. So that we have, as the final classification of plant foods (excluding the water), the following: (1) The nitrogenous substances, principally the *albuminoids*; (2) the fats; (3) the carbo-hydrates other than fibre; (4) crude fibre; (5) the ash. Or perhaps the classification may be more plainly seen in a tabular form, thus:

1. DRY SUB-STANCE.	1. NITROGENOUS SUBSTANCE.	Principally the *albuminoids*, as legumin, gluten, etc.	1. Fats.
			2. Carbo-hydrates other than fibre, as sugar, starch, etc.
	2. NON-NITROGENOUS SUBSTANCE.	1. Organic Compounds.	
2. WATER.		2. Inorganic Compounds, (the ash).	3. Crude fibre--cellulose, etc.

326. "Protein."—To all albuminoid compounds found in living bodies the name *protein* is given by scientists; and as this term is short, we shall often find it more convenient to use than the longer phrase, "nitrogenous substance." Therefore, in future, when we speak of "protein" in the animal body, we mean any nitrogenous substance found in it, no matter in what form it may exist; and similarly, when we speak of "protein" in plant substance, we mean that portion of it which consists of nitrogenous compounds, no matter of what sort.*

THE FORMATION OF FLESH.

327. "Flesh," "Fat," and "Bone," as Short Names.
—If the pupil will refer to sections 310 and 314, he will see that the nitrogenous substances of the animal body are by far the most important, and include, in fact, nearly all the solid parts of the body, except the fat and the mineral constituents of the bones. Therefore, for the sake of shortness, it is usual to speak of all the *nitrogenous substance* of the body as "*flesh*"; that is, the substance distinguished from fat and bone. And the

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*The scientific reader will notice that this phraseology is not quite correct, as account should be taken of the amides and alkaloids (see section 17 (3) (*a*)), which are also nitrogenous, but are not protein. The term "protein" should, of course, be restricted to *albuminoid* substance; but as we have purposely left out of this chapter a consideration of the amides and alkaloids, the use of the word as we have defined it is convenient.

name is quite appropriate, for the reason that a large proportion of this substance is really flesh. Similarly, for the sake of shortness, the word *"fat"* is used to denote all the *non-nitrogenous organic substance* of the body, both the real fat and other substance. Similarly, the word *"bone"* is, for shortness, often used to denote the *mineral constituents of bone*, although, it will be remembered, that much of the substance of bone (see section 314) is nitrogenous organic matter. Hence, to use the phraseology of section 326, the "flesh" of the animal body is largely protein substance; while the "fat" is non-protein. As these terms are convenient, we shall use them frequently, and the pupil must try to remember their significance.

328. Principles Difficult of Explanation.—The principles of feeding relating to the formation of flesh are far too intricate to be fully explained here; but the leading general laws may be stated, so as to be intelligible and useful, though the *reasons for their existence* cannot all be made clear. It may be said, however, that they are all founded on the observations made on many careful experiments conducted by capable and learned men.

329. The Formation of Flesh Demands a Constant Supply of Nitrogenous Substance in the Food.—Since

the main constituents of all those parts of the animal body which we have called "flesh" are nitrogenous (see section 314), it is easily seen that, for the formation of flesh, a constant supply of nitrogenous food is absolutely essential. Without it, an animal would soon die of what may be called "nitrogen starvation." Non-nitrogenous food, on the contrary, although necessary in a sense, is not, as we shall afterwards see, *absolutely essential*.

330. "Protein Consumption," "Protein Deposition," and "Circulatory Protein."—(1) Of the nitrogenous substance (or protein) taken into the body and digested, a portion, as we have seen (namely, all that portion which is not retained for the repair or building up of tissue), is oxidized in the blood, and passes out of the body through the kidneys, and other excretory organs, as *urea, carbonic acid*, etc. In the same way, the protein of the worn-out and waste nitrogenous tissues of the body is also oxidized and passed out of the body. Thus a constant oxidation and excretion, or loss, of nitrogenous substance (or protein) is occurring, the kidneys being the organs by which the excretion of the *nitrogen* (in the form of urea) is effected. This loss is called "*protein consumption.*"

(2) Again, a portion of the nitrogenous food (or protein) consumed and digested remains in the body for a longer or shorter time, being assimilated

by the body either in the form of new nitrogenous tissue, or as tissue which has replaced old worn-out or waste nitrogenous tissue. This retention and use of the nitrogenous substance of the food is called "*protein deposition*." Hence, since nitrogenous tissue is *flesh*, protein deposition is the *formation of flesh*.

(3) Thirdly, it has been found that not all of the nitrogenous food (or protein) consumed by the animal, and not immediately needed to supply the constant demand caused by protein consumption, is at once, or even at all, converted into flesh tissue. A portion of it remains for a while in the blood and other fluids of the body, partaking of their movement; and while some of this may ultimately be converted into stable flesh-tissue, most of it soon becomes oxidized and converted into substances which the kidneys, and other excretory organs, remove from the body. This fluid nitrogenous substance, awaiting either conversion into stable flesh-tissue, or oxidation and decomposition into the fluids of the excretory organs, is called "*circulatory protein.*" In well-fed animals, it causes what is called the juiciness of the flesh.

Nitrogenous Substance in the Food Considered.

331. All Nitrogenous Food Must Contribute Either to Protein Deposition or to Protein Consumption.—Since the circulatory protein becomes, in time, either a part of the deposited protein, or of the consumed protein, it follows that all the nitrogenous food given to the animal must go towards sustaining either protein deposition or protein consumption; that is, either towards producing flesh, or towards producing waste matters, as urea, carbonic acid, etc. Now, though, as is evident, a certain amount of protein consumption (that is, of oxidation and excretion of worn-out nitrogenous tissue) is absolutely necessary to the health of the animal and the proper discharge of his vital functions, yet any protein consumption more than this is *waste*.

It follows, then, that the aim of the feeder should be to secure as little protein consumption as possible, consistent with the proper discharge of all the vital functions of the animal, so that as much of the nitrogenous substance of the food as possible will be available for protein deposition, that is, for the formation of stable flesh-tissue. A further reason for this is, as will afterwards be seen, that nitrogenous food is always the most expensive and the most difficult to procur

332. Protein Consumption and Protein Deposition Both Dependent on Protein Supply.—The next principle to be stated is one which has been deduced from experiments, namely, that both protein consumption and protein deposition are dependent on protein supply, that is, on the amount of nitrogenous food with which the animal is fed. *If this amount be increased, both protein waste and flesh formation are increased; if diminished, these are diminished.* But the practical working of this principle is very much affected by the law which is stated in the next section.

333. The Law of Nitrogen Equilibrium.—This law (which also has

been established by experiments) is perhaps the most important of all the principles of feeding. It cannot be fully explained here; but its practical application will be apparent. It is thus stated by Armsby: "No matter how the feeding may be conducted, the animal body always puts itself, after a longer or shorter time, into equilibrium with the nitrogenous constituents it receives in its food above the quantity necessary to maintain it in an average condition."

The effect of this law, considered in connection with the principles laid down in sections 329 and 332, may be expressed thus: A certain minimum quantity of nitrogenous substance is necessary to prevent the starvation of the animal. An increase of the supply above this quantity causes, for a short time, a slight protein deposition, or gain of flesh. But *it also causes a rapid increase in the amount of the circulatory protein;* and as the circulatory protein is easily oxidized and decomposed, there will follow an increase of the protein consumption, till finally quite as much nitrogen is, day by day, excreted from the body by the kidneys as is taken in with the food.

Hence it is seen why the process of flesh development is comparatively *so expensive.* In order to produce a gain of flesh, nitrogenous food must be given to the animal in excess of that which is needed for protein consumption. But on account of the constant tendency to nitrogen equilibrium, it follows that for each day the animal grows older, a greater quantity of nitrogenous food is needed to produce a certain gain of flesh than was required the day before. Hence, too, it is seen how easy it is to have a *waste of fodder.* For from the tendency to nitrogen equilibrium, it follows that, if more nitrogenous substance is given to the animal than is required to supply its necessary protein consumption, the excess either will be at once removed from the blood by the kidneys, and other excretory organs, and passed out of the body; or else will be largely converted into circulatory protein, to be, for the most part, subsequently removed from the blood and passed out of the body.

334. Influence of Fat in the Animal Body.—The presence of fat in the animal body has been shown by experiments to have the effect of *decreasing the protein consumption* and *retarding the tendency to nitrogen equilibrium.* This it does by protecting the circulatory protein from oxidation. Hence fat and fattening animals gain flesh faster, and retain their store of circulatory protein longer, than lean ones.

335. Influence of Salt in the Food Supply.—Salt added to the fodder, by stimulating the activity of the kidneys, increases the protein consumption. Hence, as protein consumption is a mark of activity in the vital organs, a moderate allowance of salt is to be recommended in the feeding of animals in which energy of the vital functions is desired; as, for example, in young animals, and working oxen and horses. On the other hand, if the object be the production of flesh, then, since an increase of protein consumption is not desirable, but rather protein deposition, only such an allowance of salt should be given as is requisite to make the fodder savory, and to supply the

ordinary demands of the juices of the stomach (see section 287). It should be remarked here that great care should be exercised in giving salt to animals; for, if too much be given, the excess must be largely excreted by the kidneys, and the water necessary to carry it off will be taken from that which should be excreted by the lungs and skin, and so will interfere with the healthy working of these organs; or else it will be drawn off from that stored up in the tissues of the body itself, and so will cause the body to become lean and thin.

336. Influence of Water in the Food Supply.—As water is needed for the normal action of the digestive apparatus, and as also it is needed for the normal action of the kidneys and other excretory organs, and as it forms a large proportion not only of the fluid, but also of the solid portions of the body (see section 303), it follows that a due supply of it is absolutely necessary. But an undue supply of it increases the activity of the kidneys, and therefore causes an increase in protein consumption; that is, it causes an unnecessary waste of the nitrogenous substance (the flesh-forming substance) of the fodder supply, generally, as has been said, the most expensive portion. It will be seen, therefore, that this is another reason why salt, which induces thirst, should not be given to an animal in too large quantities.

Non-Nitrogenous Substance in the Food Considered.

337. Influence of Non-Nitrogenous Substance in the Food Supply.—Heretofore we have been considering the food supply as nitrogenous substance simply, since this sort of substance is absolutely essential to the formation of " flesh " in the animal, and therefore to its life and well-being; while, in a sense, the animal is independent of non-nitrogenous substance, and may exist without it. But as all proper foods are more or less complex in their composition, we must now consider what influence the other principal components of the feeding-stuffs, that is, fat, and the carbohydrates (see section 325), exert upon the formation of flesh.

338. Influence of Fat in the Food Supply.—The influence of fat in the food supply on the formation of flesh (that is, of fat *along with* nitrogenous substance) has been ascertained by experiments. It produces several effects, which may be best stated singly :

(1) *It decreases the protein consumption and thereby increases the protein deposition. That is, it aids in the formation of flesh indirectly.* The effect of this principle may be illustrated thus: Supposing an animal to be losing flesh under a certain supply of food; the addition of a little supply of fat, by decreasing the protein consumption, may cause the animal to gain in flesh, although the fat in the food cannot go towards the formation of flesh directly.

Moreover, from this principle it will be seen how a mixed food is the more economical. For while it must be remembered that an animal would die of nitrogen starvation if it were fed on fat alone, yet, on the other hand, it has been found that, if an animal is fed on nitrogenous food alone, a *much larger*

quantity of food is required to keep it in a state of neither gaining flesh, nor losing it, or to cause it to gain flesh, than if a *part* of the nitrogenous food were replaced by fat. Moreover, it must be remembered that the nitrogenous constituents of food are generally the dearest.

(2) *But while fat in the food decreases the protein consumption, it does so independently of the protein supply.* As stated in section 332, the protein consumption increases and diminishes with the protein supply, and all that the fat does is to diminish it by a certain quantity, which will be the same no matter how large the protein supply in the food may be. This fact is important, for when once the feeder has found what proportions of nitrogenous substance and fat in his food-supply produce a result, as regards the sustenance of the animal or the formation of flesh, that is favorable to his purpose, he may then be certain that increasing the supply of nitrogenous food will have the effect, *mainly,* of increasing the protein consumption, that is, of producing waste, and so may not only be no gain to him, but, on the contrary, loss.

(3) *The addition of fat to the food retards the tendency to nitrogen equilibrium.* We have seen (section 333) that an increase of protein supply is generally followed by an increase in circulatory protein, but that this, in its turn, is rapidly decomposed and added to the protein consumption. Hence equilibrium is soon established between the nitrogen supply and the protein waste. But the presence of fat in the food seems to favor the formation, out of the protein supply, of stable flesh-tissue (in place of *part* of the circulatory protein), which is not so easily oxidized and decomposed. As a consequence, *there will be a daily gain in flesh, which may go on for some time* before nitrogen equilibrium is established ; and which, though not considerable in any one day, will be very considerable on the whole. And it has been found that *this gain of flesh will continue longer with a medium supply of nitrogenous substance in the food than with a large supply.*

It will be noted by the pupil that the effect of fat in the food on the formation of flesh is very similar to the effect of fat in the body itself (see section 334).

339. General Remarks on the Influence of Fat.—

What has been said about the beneficial effect of fat on the formation of flesh must be modified by the consideration, that while fat in small quantities exerts a favorable influence upon the animals fed with it, larger quantities, by disturbing the digestion and impairing the appetite, are found to be injurious. However, the ordinary feeding-stuffs made use of by the animals of the farm contain but little fat, and hence these injurious influences are not likely to be exerted, unless special fatty foods are employed.

It will be seen in the following sections (340 and 341) that the influence of fat on the formation of flesh is very similar to the influence of the carbo-hydrates, and that the carbo-hydrates are found largely in all the ordinary foods of farm animals. Hence, in considering in what proportions certain feeding-stuffs should be taken, in order to provide a suitable food for animals for any given purpose, as fattening, or producing milk or wool, or the main-tenance of growing animals, it is usual to reckon the fats in with the carbo-hydrates. How this is done will be explained in sections 347 and 363.

340. Influence of Carbo-Hydrates in the Food Supply.—The influence of the carbo-hydrates on the formation of flesh has been found by experiments to be similar to the influence of fat. It will therefore be only necessary to state the conclusions established, without remark :

(1) *Carbo-hydrates in the food decrease the protein consumption, and thereby increase the protein deposition.*

(2) *But while carbo-hydrates in the food decrease the protein consumption (and thereby increase the protein deposition), the protein consumption depends, as regards quantity, solely on the protein supply.*

(3) *Carbo-hydrates in the food retard the tendency towards nitrogen equilibrium, and therefore cause a longer continued gain of flesh than would be effected by nitrogenous food simply.*

Experience has shown that *the proportion of protein deposition to protein consumption is greatest* (that is, that *the greatest gain of flesh is made*) when the food ration is so constructed that the proportion of carbo-hydrates to albuminoids in the food (that is, of non-protein to protein substance) is *large. But the proportion must not be too large*, or else there will not be enough of protein substance in the food consumed to supply the albuminoid material required for the new flesh tissue. This part of the subject will be taken up more fully in subsequent sections. See also section 352.

341. Carbo-Hydrates Equivalent to Fat.—As stated in the previous section (compare also section 338), *the carbo-hydrates, as regards the formation of flesh, produce the same effects as fat.* This fact is of the utmost importance in feeding; for, in the first place, fodders containing fat are comparatively costly; secondly, they are difficult of digestion by the ordinary animals of the farm; thirdly, an undue amount of them is liable to produce injurious effects, such as impairment of the appetite, etc. On the other hand, fodders containing the carbo-hydrates in large proportions are comparatively cheap, being indeed those most commonly grown on the farm; and, moreover, they are readily eaten and digested by all the animals of the farm. Hence the comparative cheapness and abundance of the carbo-hydrates enable the stockman to maintain his animals in an

average condition, and even to give them the food necessary for growth, or (as we shall afterwards see) for the production of fat, or of muscular exertion, at a much less cost than if he were compelled to have recourse to the comparatively expensive nitrogenous foods only, or to the nitrogenous and fatty foods only.

THE FORMATION OF FAT.

342. Formation of Fat.—The principles of feeding relating to the formation of fat are by no means so well established as those which relate to the formation of flesh, and therefore we shall only very briefly refer to them.

343. Food Fats, Albuminoids, and Carbo-Hydrates, all Concerned in the Formation of Body Fat.—The sources of the fat in the body are said to be three: (1) the fat in the food; (2) the albuminoids or nitrogenous substance in the food; (3) the carbo-hydrates in the food. Upon this statement the following remarks may be made: (1) The fats in the plant substances used as feeding-stuffs for animals are very similar in their composition to the fat of the animal body; and there is no doubt that, in a fattening animal, a great portion of the fat of the food is absorbed from the alimentary canal and deposited in the body as body-fat. (2) It is now well established that the albuminoids (or nitrogenous substance) of the food are also direct sources of body-fat, and also that they contribute indirectly towards its formation. (3) Whether the carbo-hydrates of the food are direct sources of fat in the animal body is not thoroughly established; but the weight of authority is to the effect that they are; and, as will be seen in section 346, if they do not conduce to the formation of fat directly, they undoubtedly do so indirectly.

Moreover, it is established that in a well-nourished animal some of its fat is formed out of the *circulatory protein*, by its oxidation into body-fat and urea. See also section 345.

344. Influence of Fat in the Food.—As stated in the previous section, *the fat of the food may be absorbed from the alimentary canal and deposited in the body as body-fat.* But it tends in another way to the production of fat in the body: *it protects from oxidation the body-fat already formed.* That is, the oxygen in the blood, instead of uniting with the carbon of the body-fat already formed to produce carbonic acid gas and vital heat, unites more readily with the fat that is newly come from the food, and not yet deposited as body-fat.

345. Influence of Protein in the Food.—As stated in section 343, *fat in the body may be formed directly from the protein substances (or albuminoids) of the food*, their nitrogen being thus separated from them and excreted by the kidneys in the form of urea.* But this fat, before it is deposited as body-fat, and while still in the blood, is (like the fat of the food) much more readily attacked by the oxygen of the blood than body-fat already formed; hence we see that *a second influence of the protein in the food is to protect from oxidation the body-fat already formed*.

346. Influence of Carbo-Hydrates in the Food.—As stated in section 343, *whether the fat in the body can be produced from the carbo-hydrates of the food is uncertain*. But it is certain that it is produced both from the fat in the food and the protein in the food. And it is further certain that the carbo-hydrates of the food, while in the blood, are more readily attacked by the oxygen of the blood than either body-fat, or the absorbed fat of the food, or the fat formed from protein. Hence we have this great principle, that *the carbo-hydrates of the food protect from oxidation the fat of the body, and the fat absorbed from food, and also that newly-formed from protein*. Therefore, whether it be true or not, that the carbo-hydrates conduce *directly* to the formation of fat, it is true that they conduce *indirectly* to this end.

347. Relative Value of Fat and Carbo-Hydrates.—We have seen (see section 341) that, for the production of *flesh* (that is, by decreasing the protein consumption), the carbo-hydrates are equivalent to fat, weight for weight. But, as will be seen in section 356, it is found that, for the production of *heat*, fat is 2.5 times more effective than the carbo-hydrates. It was for a long time thought that this same ratio of 2.5 held for the production of *fat*, and that, therefore, in calculating, for fattening purposes, how much of carbo-hydrates a given quantity of fat in the food is equivalent to, it was necessary to multiply its weight by 2.5; and, indeed, the pupil will often meet this statement in books and papers. But it is now known that this ratio is too great, and that the ratio 1.75 is nearer the truth. Therefore, since for the production of *flesh* the fats and the carbo-hydrates are equivalent, weight for weight, and although for the production of *fat* the fats are superior to the carbo-hydrates, yet as the fats generally form but a small percentage of any feeding-stuff, it follows that *no serious error will be made if, for general feeding purposes, the digestible fats and the digestible carbo-hydrates are taken as entirely equivalent, weight for weight*. [NOTE.—This does not mean, however, that fat in the food may be wholly replaced by carbo-hydrates. It would seem that for the production of *body-fat* (see section 344), and for the *rapid* production of *muscular exertion* (see section 359), and probably also for the production of *milk* (see section 370 (14)), a

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*The change undergone in this conversion of albuminoid substance to fat and urea is far too intricate to be explained here. It may, however, be described generally as an oxidation.

certain, though small, percentage of fat in the food is *absolutely required;* but decisive experiments have not as yet been made in the matter.]

348. Influence of Fat in the Body.—In the animal body, when rich in fat, the oxidation of the fat already stored up, and also the oxidation of the fat in the food, is greater than when the body contains little fat. Hence, from both these causes, the accumulation of *fat* is more retarded in a body already rich in fat than in one containing but little fat. But, on the other hand, it must be remembered (see section 334) that the presence of fat in the body protects the circulatory protein from oxidation, and therefore is favorable to the formation of *flesh;* and also (especially if the animal is matured and has stopped growing) to the formation of *fat out of the protein* (see section 343).

349. Influence of Water.—Excessive drinking, by increasing the action of the kidneys, increases both the consumption of fat and the consumption of protein, and therefore interferes with the accumulation of fat. Watery food and too much drinking, therefore, are to be avoided, if the formation of fat be the object of the feeder.

350. Influence of Temperature.—If the temperature of the stall in which the animal is kept be too high, two injurious effects follow: (1) The animal drinks too freely, and this, as is seen by the last section, interferes with the deposition of fat; (2) the animal perspires too freely, and therefore is subjected to excessive evaporation, which, as will be seen in section 357, causes a loss of heat, and therefore (to make good the loss) an increase of oxidation, that is, a loss of body-substance, usually fat substance. On the other hand, if the temperature of the stall be too low, then, in order to maintain the normal heat of the animal body (see section 357), an increased oxidation is also necessary; that is, a loss of food substance is occasioned, and perhaps a loss of flesh or fat (for the most part, fat) already formed.

351. Influence of Muscular Exertion.—As will be seen in section 359, muscular exertion can be effected only by the expenditure of heat, that is, by the oxidation of food, or of already-formed tissue, of which the easiest to oxidize is generally the fat. Hence, since muscular exertion not only tends to the oxidation of fat tissue already formed, but also of constituents in the food which will go towards making fat, too much movement in fattening animals is injurious, and therefore to be avoided. And this is true not only of outward motions, but also of the internal movements of the body concerned in digestion. Hence, it is easily seen how it is that concentrated and easily digested fodders contribute materially towards speed in the fattening process.

352. Choice of Foods for the Formation of Fat.—The process of fattening animals for the market is so important to the farmer and stockman that it will be well to summarize the principles laid down in the preceding sections, and see how they affect the choice of foods necessary to secure an accumulation of fat in the fattening animal. And this will be better done by first considering the choice of foods necessary to maintain an animal in a *constant* condition, that is, neither gaining substance, nor losing it.

(1) To maintain an animal in a constant condition, only a certain minimum amount of nitrogenous and non-nitrogenous constituents in its food will be necessary; viz., the amount necessary to make good the losses occasioned by the excretory organs. But if the animal has been previously plentifully supplied with nitrogenous fodder, its body will contain much circulatory protein (see section 330); and, therefore, to maintain this amount of circulatory protein undiminished, considerable nitrogenous substance in the food will be required. If the animal has been poorly fed, its body will have but little circulatory protein; and, to maintain it in the same condition, only comparatively little nitrogenous substance in the food will be required. Again, if the body is fat, a less quantity of nitrogenous substance in the food will be required (since the protein consumption will be less—see section 334) than if the body be lean.

(2) But if the animal is to be fattened, while it must be remembered that a certain amount of nitrogenous substance in the food is absolutely necessary, both to make good the unavoidable protein consumption, and to go towards forming new tissue, both of flesh and fat, yet the important fact is, that *the greater the amount of the non-nitrogenous substance that is taken into the system, the greater will be the amount of already-formed body-fat that will be protected from oxidation (see sections 344 and 346); and the less also will be the protein consumption (see sections 338 (1) and 340 (1)), and therefore the greater the supply of protein available for new tissue formation.* In other words, the greater the amount of carbo-hydrates and fat taken into the system along with the albuminoids that are consumed, the greater will be the production of both flesh and fat. Therefore, in making a choice of foods for fattening purposes, the object will be to see, *first, that enough of nitrogenous substance is present (both for necessary protein consumption, and for the formation of new tissue, both of flesh and fat); and second, to secure along with it as great a consumption as possible of non-nitrogenous food.* This matter will be taken up more minutely in subsequent sections.

THE PRODUCTION OF MILK.

353. What Milk is.—Milk is an organized product of the body, the same as the fat or the flesh; and not a waste product, such as that which the excretory organs, the lungs, the skin, and the kidneys, are instrumental in removing from the body. It is produced in certain glands of the udder, called the milk glands. These glands have the power of forming cells of nitrogenous (protein) substance, containing globules of fat; also of secreting a more or less watery fluid. As new cells are formed, the earlier formed ones are broken up, whereupon the fat-globules, thus released, and the nitrogenous substance of the broken cell-walls, float about in the fluid substance, the whole constituting milk. The

fat-globules are the cream of the milk ; and when separated from the remaining portion, they form *butter*. They constitute about 4 or 5 per cent. of the whole. The rest of the milk consists of water, nitrogenous matter, sugar, and ash. The water is about 88 per cent. of the whole. The nitrogenous matter consists of albuminoids, principally casein (see section 310), a substance not found elsewhere in the animal body. It forms about 2 to 5 per cent. of the whole. The sugar is known as *lactose*, or *milk-sugar*. It forms from 3 to 5 per cent. of the whole. The ash of milk consists principally of potash and phosphate of lime. It constitutes only a small portion of the whole—less than 1 per cent.

It will thus be seen that the water of milk is about 88 per cent., and the dry matter about 12 per cent.; and that of the constituents of the dry matter, the casein, butter-fat, and milk-sugar, exist in about equal proportions, while the ash is very much less than any one of them. These proportions differ, however, not only with every sort of animal, but with every breed of every kind of animal, and almost with every individual of every breed.

With respect to the casein, it should be said that it is the distinctive ingredient of cheese. The casein, being an albuminoid, is easily coagulated, or solidified (see section 310), the substance used therefor being rennet. In the process of solidifying, it entangles much of the butter-fat along with it; also some water ; the resulting solid, when separated from the rest of the milk (the whey), and suitably prepared, is *cheese.*

354. Influence of Food.—The quantity and quality of the milk produced by any individual animal depend primarily upon the development of the milk glands in the animal ; hence, for the production of milk, the selection of the animal, and also of the breed of the animal, is all important. But, beyond this, the influence of the food given to the animal is also considerable. The albuminoids of the fluid substance secreted in the milk-glands must come, directly or indirectly, from nitrogenous substance supplied in the food. It is probable, also, that the fat of the milk, and likewise the sugar (in part, at least), are formed out of albuminoids, and therefore must depend upon the

nitrogenous constituents of the food.   Moreover, the cells of the milk-glands, in which the fat-globules are formed, and upon whose number the *quantity* of the milk produced depends, consist largely of albuminoids, which also must come directly or indirectly from the food.   So that it follows that *the greatest yield of milk, as well as that with the largest percentage of solid substance, will be obtained from food rich in nitrogenous constituents.*

THE PRODUCTION OF HEAT.

355. The Animal Organism Requires a Constant Supply of Heat.—The production of flesh, fat, and milk, which we have previously considered, is the result, in each case, of certain changes effected upon the food, both mechanical and chemical.   But these changes cannot be effected without the expenditure of vital energy.   That is, in order to maintain itself and discharge its functions, the animal, either as a whole, or by one or more of its external or internal organs, must put forth a certain amount of conscious or unconscious *effort ;* as, for example, it must convey its food to its mouth, and from its mouth to its stomach, and from its stomach to those parts of the body where it is needed, in the meantime changing both the form and the condition of the food.   Moreover, it must necessarily exercise its power of locomotion, and, perhaps, assist in the performance of labor for man.   All this is *work*, and just as the steam-engine needs heat to accomplish the work which it does, *so also does the animal body need heat to accomplish the work which it does.*

But, as has been seen in sections 300 and 317, in the constant process of *oxidation*, or *burning*, of waste tissue and of food substance, which is going on everywhere in every part of the body to which the blood reaches, *heat is produced.*   So that we have, therefore, not only *a constant demand for heat* in all the vital processes of the animal organism, and in all its movements, both external and internal, but also *a constant supply of it* in that produced by the oxidation of the food and the already-formed tissues of the body.

356. The Heat Supply is Dependent on the Food Supply.—It is thus seen that the heat supply must all

ultimately come from the food supply, for the tissues that are oxidized (or burnt) must have come originally from the food. The oxidation (or burning) goes on constantly everywhere, wherever the minute blood-vessels penetrate (see section 300). Moreover, it is maintained with no gain of substance to the body, but, on the contrary, with loss. For the products of the combustion, carbonic acid gas, water, and urea, are, as we have seen (section 302), waste products, and must be got rid of by the excretory organs. It is estimated, that *of the whole quantity of food eaten by an animal, about four-fifths are required to sustain the demand occasioned by the production of heat.*

While the nitrogenous substance, the fats, and the carbo-hydrates of the food, are all oxidizable, and may therefore be all used as sources of heat, the fats and the carbo-hydrates are the most suitable for this purpose, since their oxidation while in the blood is much more readily effected than that of nitrogenous substance. Moreover, they are, on the whole, much cheaper. Again, since the carbo-hydrates, although they do not furnish so much heat, weight for weight, as the fats (the fats in this respect being 2.5 times superior to them), are yet so much more abundant, and therefore so much cheaper, it is easily seen why, in a proper food supply, they should form a much greater proportion than either the fats or the nitrogenous constituents of food.

357. How the Heat of the Animal Body is Regulated.

—The work done by the animal body in the discharge of its functions is of two kinds, external and internal. *External work* may be illustrated by the drawing of a vehicle, or the bearing of a burden, or the moving of the body itself, in whole or in part, from one place to another. *Internal work* includes such exertions as the muscular effort of the heart, lungs, etc., the operation of digesting the food, the carrying it from one part of the body to another, the building it up into complex chemical compounds, as tissue, both of flesh and fat, and the removal of the waste products from the body. All this work requires the constant supply of a considerable quantity of heat; and this supply comes, as we have seen, from the oxidation, or burning, of food substance and waste tissue going on constantly in the body everywhere. The production of so much heat in the body, were not some of it carried off, would soon raise the temperature of the body to an intolerable degree. But this ill effect is prevented by the constant *dissipation of heat* caused by:

(1) The conduction and radiation of heat from the skin.

(2) The evaporation of water from the skin and lungs.

(3) The warming of the food and drink taken into the stomach, and the air taken into the lungs.

By these means, the excess of heat above what is required for the use and comfort of the body is easily carried off.

On the other hand, it would at first sight seem, since the stomach, the air passages, and the outer surface of the body, are those parts which are most subject to the loss of heat, that they would be much cooler than the other parts; or, in other words, that the temperature of the body would be much higher in some parts than in others. But owing to the fact (1) that the blood is being constantly heated throughout its whole extent by the oxidation which is going on in every part of the body to which the blood penetrates, and (2) that the blood is in a constant state of motion, and so, before it is over-heated in one part, it is carried off to some cooler part, and, before it is too much cooled in that part, it is forced off again to some warmer part, it follows that the body, as a whole, remains pretty much at a constant temperature, the same throughout all its parts, namely, about 99°. Even a slight variation from this normal temperature is unusual, and indicates a serious disturbance in the animal organism, betokening the presence or oncoming of disease.

358. Practical Remarks on Heat and Temperature.

--(1) If an animal be kept in a temperature below the normal temperature of its body, it will necessarily lose heat by radiation, and the loss must be made good by increased oxidation, that is, by the consumption of more food, or of the substance of the animal body, as fuel. On the other hand, the higher the temperature in which the animal is kept, the greater will be its perspiration, and the consequent evaporation of water from the surface of its body, and therefore the greater will be the loss of heat in that way. So that it follows that a medium temperature is the most effectual in preventing heat waste, and therefore the one that will be the most economical of food.

(2) Similarly, it will be seen that, if water or food be taken into the body at a low temperature, before it can be dealt with

by the animal organism and be made a part of the fluid or solid substance of the body, it must be heated to the normal temperature of the body; and that this heating or warming can be done only at the expense of an increased consumption of fuel, that is, of food. To what extent, then, food and drink should be warmed before being given to the animal, is a question of comparative expense.

PRODUCTION OF MUSCULAR EXERTION.

359. Production of Muscular Exertion.—We have seen (section 355) that a constant supply of heat is necessary in order that the animal organism may accomplish the work required of it in discharging its functions; and that this work is of two kinds, external and internal. External work may all be described as *muscular exertion.* Internal work is largely muscular exertion also; namely, that required to effect the movements of the organs concerned in the various vital processes. Muscular exertion, like every other sort of work, demands a constant supply of heat to sustain it, the greater the exertion, the greater the quantity of heat required. And of course this heat must all come, directly or indirectly, from the food. Beyond this, the relation between food-supply and muscular exertion is unfortunately not well understood. It is certain, however, that the food given to the animal to support muscular exertion must be something more than mere fuel; in other words, that it must be partly nitrogenous, and not, like the fats and the carbo-hydrates, merely carbonaceous. And for the production of muscular exertion in any considerable degree, it is also certain that not only is a *liberal supply* of food necessary, but also that the food shall be *rich in nitrogenous substance.* The whole matter may be summed up thus: *Muscular exertion is dependent on food supply; the greater the exertion to be made, the greater must the food supply be, and the greater also must be the proportion of nitrogenous substance in it.*

THE FEEDING-STUFFS.

360. Varying Values of all Feeding-Stuffs.—As will have been seen from the preceding sections, the feeding-stuffs all vary greatly in their nutritive constituents, some being more nitrogenous than others, some more fatty, and so on. Not only

is this so, but they all vary greatly in their digestibility, and in the degree with which they are relished by different animals. Moreover, they further vary in all these respects by reason of the different soils on which they are grown, the different methods by which they are cultivated, the different times and manners in which they are harvested, and the different ways in which the feeder prepares them for consumption. We cannot possibly discuss all these matters here—to do so would require a book in itself—but the following table will give the pupil an idea of the relative proportions and digestibility of the constituent nutrients of the more common feeding-stuffs; but it must be understood that only an average statement is intended in each case:

TABLE OF THE CONSTITUENTS OF THE ORDINARY FEEDING-STUFFS, AND OF THEIR AVERAGE DIGESTIBILITY.

The figures printed in ordinary type show the percentage of composition of each constituent.

The figures printed in italics show the percentages of these quantities which are digestible.

	Total dry matter.	Nitrogenous Substance (Albuminoids).	Fats.	Carbo-hydrates other than fibre.	Crude fibre.	Ash.	Total amount of water.
Pasture grass..........	25.0	3.0 *75*	0.8 *66*	13.1 *79*	6.0 *73*	2.1	75.6
Timothy (green).......	31.0	2.7 *70*	0.8 *65*	14.9 *79*	10.5 *60*	2.1	69.0
Red clover (green).....	19.8	3.6 *73*	0.7 *02*	8.5 *76*	5.6 *55*	1.4	80.2
Rape (green)..........	14.0	2.9 *71*	0.6 *60*	3.7 *60*	5.2 *29*	1.6	86.0
Meadow hay..........	85.7	9.5 *57*	2.3 *46*	40.3 *03*	27.1 *58*	6.5	14.3
Timothy hay..........	86.5	6.2 *57*	1.7 *46*	45.8 *03*	28.9 *58*	3.9	13.5
Clover hay............	83.3	11.0 *60*	3.2 *59*	32.9 *09*	29.9 *47*	6.3	16.7
Wheat straw..	85.7	3.1 *26*	1.2 *27*	37.5 *40*	40.0 *52*	3.9	14.3
Barley straw.	85.7	3.4 *30*	1.4 *38*	34.7 *51*	41.8 *52*	4.4	14.3

	Total dry matter.	Nitrogenous substance (Albuminoids).	Fats.	Carbo-hydrates other than fibre.	Crude fibre.	Ash.	Total amount of water.
Oat straw............	85.7	4.0 / *38*	2.0 / *30*	35.6 / *42*	39.7 / *61*	4.4	14.3
Pea straw............	85.7	7.3 / *60*	2.0 / *46*	32.3 / *61*	39.2 / *52*	4.9	14.3
Wheat chaff..........	85.7	9.5 / *82*	2.3 / *40*	40.3 / *51*	27.1 / *72*	6.5	14.3
Oat chaff............	86.4	4.9 / *50*	1.4 / *51*	37.4 / *47*	31.7 / *67*	11.0	13.6
Potatoes.............	25.0	2.0 / *100*	0.3 / *100*	20.7 / *100*	1.1 / *100*	0.9	75.0
Mangels.............	12.0	1.1 / *100*	0.1 / *100*	9.1 / *100*	0.9 / *100*	0.8	88.0
Carrots.............	14.1	1.3 / *100*	0.25 / *100*	9.65 / *100*	1.9 / *100*	1.0	85.9
Turnips.............	8.65	1.0 / *100*	0.15 / *100*	5.8 / *100*	0.9 / *100*	0.8	91.35
Wheat	85.7	13.2 / *?*	1.6 / *?*	66.2 / *?*	3.0 / *?*	1.7	14.3
Rye	85.7	11.4 / *?*	1.7 / *?*	67.8 / *?*	3.0 / *?*	1.8	14.3
Barley	86.2	11.2 / *77*	2.1 / *80*	65.5 / *87*	5.2 / *20*	2.2	13.8
Oats................ *(in horses)....*	86.3	12.0 / *87*	6.0 / *78*	56.6 / *77*	9.0 / *26*	2.7	13.7
Peas................ *(in swine)....*	86.8	22.4 / *88*	3.0 / *58*	52.6 / *97*	6.4 / *74*	2.4	13.2
Corn (common)....... *(in swine)....*	87.3	10.6 / *85*	6.5 / *76*	65.7 / *84*	2.8 / *34*	1.7	12.7
Corn (sweet)........ *(in swine)....*	91.4	12.1 / *85*	8.0 / *76*	67.4 / *94*	2.0 / *34*	1.9	8.6
Flax seed...........	88.2	21.7 / *87*	35.6 / *91*	19.6 / *91*	7.9 / *26*	3.4	11.8
Linseed cake........ *(in cattle).....*	87.8	29.5 / *87*	10.0 / *91*	29.8 / *91*	9.7 / *26*	8.8	12.2
Cottonseed cake (decorticated) *(in sheep)*	90.0	40.9 / *74*	16.4 / *91*	15.8 / *46*	9.0 / *23*	7.9	10.0
Wheat middlings.....	87.1	14.6 / *88*	3.0 / *80*	63.8 / *80*	3.1 / *20*	2.6	12.9
Wheat bran.......... *(in cattle)....*	87.0	14.5 / *88*	3.5 / *80*	53.6 / *80*	9.4 / *20*	6.0	13.0
Brewers' grains......	22.3	4.6 / *85*	1.6 / *80*	9.9 / *75*	5.0 / *50*	1.2	77.7
Fresh cow's milk.....	12.0	3.2 / *100*	3.6 / *100*	4.5 / *100*		0.7	88.0
Skimmed milk........	10.0	3.5 / *100*	0.7 / *100*	5.0 / *100*		0.8	90.0
Butter-milk..........	9.9	3.0 / *100*	1.0 / *100*	5.4 / *100*		0.5	90.1
Whey...............	7.2	1.0 / *100*	0.6 / *100*	5.0 / *100*		0.6	92.8

361. Practical Remarks.—The following remarks are based on the table, and will be found practically useful :

(1) *Pasture grass, green meadow hay, timothy, and clover.* Young and growing plants contain (relatively to their total solid matter) more nitrogenous substance, and less fibre, than those more mature ; the reason being that, in the mature plant, much of the nitrogenous substance previously formed and deposited in the stem and leaves has been transferred to the seed, and that the digestible carbo-hydrates of the young plant have been more or less turned into comparatively indigestible cellulose (see section 25). Hence, young and tender grass is more nutritious (that is, it has a greater supply of available nitrogenous substance and carbo-hydrates other than fibre) than that which is older, and it is also more digestible.

(2) *Timothy hay.* Timothy and other sorts of hay are much affected by the process of curing or saving employed. Hay that is wet in curing loses both in nitrogenous substance and in soluble carbo-hydrates, and, at the same time, gains in crude fibre. Hence it becomes both less nutritious and less digestible.

(3) *Clover hay.* It will be noticed from the table that green clover and clover hay are both comparatively rich in nitrogenous substance. Clover hay, however, is even more affected by rain during the process of saving than the other sorts, since it loses a greater percentage of soluble carbo-hydrates than the other sorts, and an equal percentage of nitrogenous substance.

(4) *The cereal straws.* It will be seen from the table that cereal straw, though poor in nitrogenous substance, is rich in carbo-hydrates and in the crude fibre ; and its crude fibre is by no means indigestible, especially for cows and sheep, since their power of rumination enables them to digest it better than horses or pigs can do. Therefore, straw constitutes a feeding-stuff which is quite valuable to the farmer, the more so because of its abundance. But from its deficiency in nitrogenous matter (see table), it is not suited to form a ration by itself. From the table, it will be seen that oat straw is usually the richest in nitrogenous substance ; barley straw comes next, and is valued for milch cows ; wheat straw comes next ; and rye straw is the poorest, and, moreover, the least digestible, of all. Sheep are able to make the best use of straw. Pigs, on the other hand, being naturally carnivorous, are not able to digest it well, and therefore cannot use it to much advantage.

(5) *Pea straw.* Pea straw differs from the straw of the cereals, just as clover hay differs from other hay ; that is, it contains more nitrogenous matter, and less non-nitrogenous matter. Moreover, it is (on the whole) much more digestible. Peas, beans, and clover, are all leguminous plants, and hence it may be remembered that the leguminous plants are all comparatively rich in nitrogenous substance. They owe this quality to the the presence of legumin, one of the albuminoids (see section 17 (4) (*a*)). From what has previously been said (in paragraph (1) above), it will be seen that

the earlier the straw is cut, the more nitrogenous substance it is likely to contain.

(6) *Chaff.* Wheat chaff and oat chaff are generally richer in nitrogenous substance than the respective straws; and when fed in proper quantities, they are found to be more digestible and palatable.

(7) *The tubers and roots.* The tubers and roots (potatoes, mangels, carrots, and turnips) are all remarkable (see table) for the large amount of water which they contain; but as their dry substances are almost wholly digestible, it follows, at the same time, as will be seen from the table, that they are also remarkable for the comparatively large amount of carbo-hydrates contained in them which are available without waste. They are, therefore, rightly described as *concentrated fodders;* and while their composition shows that they cannot be used alone, both because they lack a sufficiency of nitrogenous substance, and because, being very watery, they do not possess the volume necessary to the food of ruminating animals, yet when added to fodders which, taken together, are both bulky and nitrogenous (as for example, hay or straw, and grain or oil cake), they produce excellent results. Hogs, since they do not require a bulky fodder, can very advantageously make use of these foods (especially potatoes), with the addition simply of some nitrogenous fodder, such as skimmed milk, or sour milk, or whey.

(8) *The cereal grains.* The cereal grains—wheat, rye, barley, oats—are of all fodders the most important. The reason for this is, that in the experience of the whole world, and in all time, they have been found to be the best fodders for sustaining muscular exertion. Wheat, indeed, is so valuable as a food for man that it is rarely used as food for animals; and for the development of young animals, or for the performance of severe work by those that are more mature, no fodder has been found equal to the other cereal grains, especially oats. As will be seen from the table, these grains contain their nitrogenous substance, carbo-hydrates, and fat, in combination with but little water, and with comparatively little crude fibre; and moreover, as may be judged from comparing their weights with those of other foods, these are stored in but little space. Hence they are what are called "*highly concentrated fodders*'; and their concentration, together with their large digestibility, results in a great saving of digestive labor to the animals fed upon them. This characteristic, and their happy combination of nutrients, are the two chief causes of their eminent suitability as food for working animals. Owing to their concentration, however, they are apt to disturb digestion, and therefore must be used as food with due precaution

(9) *Corn.* As will be seen from the table, common corn contains less nitrogenous matter than the cereal grains, and more carbo-hydrates and fat (taken together) than any of the cereal grains except oats; therefore, it is not so valuable for hard-working animals, because these require very considerable nitrogenous substance (see section 359). But for purposes of fattening, and particularly in fattening swine, corn has been found to produce

the most excellent results. This, no doubt, is due to the comparatively large amount of fat which it contains (see table). Sweet corn (see table) is richer in nitrogenous substance than common corn, and is therefore, on the whole a more nutritive fodder for general feeding purposes; it is also richer in carbo-hydrates and fat, and therefore is better for fattening purposes.

(10) *Peas.* Peas (see table) contain a much larger percentage of nitrogenous substance than the grains of the cereals. Richness in this substance is a characteristic of all the legumes, that is, of peas, beans, vetches, and clover. Moreover, peas are of large digestibility. Therefore they form a highly concentrated nutritious fodder, and are well suited as food for working animals; but owing to their comparative deficiency in non-nitrogenous substance, they should form only a part of the grain ration.

(11) *Oil cake, cotton cake, etc.* The seeds of the flax plant and of the cotton plant contain much nitrogenous substance; therefore when the oil which also abounds in them (but which is more valuable for other purposes than for feeding) is expressed, they constitute a very concentrated fodder of highly nutritive value, especially suitable to be used with feeding-stuffs deficient in nitrogenous substance, such as straw, or poor hay. This food is generally sold in the form of cake or meal. It is highly digestible, but, like all concentrated foods, it must be fed with care, since undue quantities of it are apt to disturb digestion. It has been found very valuable in feeding for milk and for fattening.

(12) *Wheat bran.* From the table it will be seen that wheat bran contains a higher percentage of nitrogenous substance than any of the cereal grains mentioned, even wheat itself. Moreover, since its digestibility is large, its value as a fodder is very great, especially for cattle and sheep. For working horses, much of it is not desirable, perhaps because it contains a large proportion of innutritious fibre, which must be got rid of in the digestive process. *Wheat middlings* differ from wheat bran principally in containing less crude fibre and ash, and, proportionately, more of the carbo-hydrates other than fibre (as starch, etc.). It is therefore, perhaps, a better food for fattening purposes.

(13) *Brewers' grains.* In brewers' grains, the starch (a non-nitrogenous substance) of the grain has been extracted in the making of the malt, and therefore what remains is relatively richer in nitrogenous substance than the original grain. And as these grains are very digestible, and are agreeable to cattle, they form an excellent fodder for fattening, or for milk. But, as will be seen from the table, they are very watery, and therefore are not suitable for the production of work.

(14) *Skimmed milk.* Skimmed milk differs from fresh milk principally in loss of butter-fat. It is comparatively rich in nitrogenous substance, and is therefore suitable to be fed, especially to hogs, along with potatoes, or other feeding substances, that are poor in this substance. For young and growing hogs, skimmed milk, potatoes, and wheat middlings, make an excellent ration, the middlings having the effect of giving more concentration to the fodder.

(15) *Whey.* Whey, though by no means so nutritious as skimmed milk, since it has lost both fat and nitrogenous substance, is yet considerably nutritious, since its nitrogenous substance forms so large a proportion of its total dry matter. As will be seen from the table, its dry matter is but a small percentage of the whole, and therefore some more solid food, such as grain, ought to be fed along with it. But its constituents are all digestible, and as it is very palatable to hogs, it forms for them a most excellent fodder.

FEEDING STANDARDS.

362. Meaning of the Term "Feeding Standard."—

One of the principal objects of this chapter is to make the pupil acquainted with those principles of animal nutrition and food composition which are necessary to an intelligent appreciation and proper use of "the feeding standards." From the foregoing sections, it will be seen that what the feeder has principally to look out for in the selection of his feeding-stuffs, is that they contain digestible nitrogenous substance, carbo-hydrates, and fat, in sufficient quantities and in right proportions to effect his purposes; for the other necessary constituents of food, namely, water and ash, are usually present in sufficient quantities to meet the requirements of the animal organism, or, if not, can easily be supplied. A feeding standard is simply *a statement of the proportionate amounts of digestible nitrogenous and non-nitrogenous substance which experience has shown to be best suited to effect a given purpose in feeding, such as mere maintenance, or the production of work, or of flesh, or of fat, or of milk.* But such a statement can be of little value unless it is expressed in precise terms; and the preceding sections have been necessary to acquaint the pupil with the meaning of the terms used. As the pupil grows older, his own experience will, it is hoped, enable him better to understand the whole question of feeding; but in order that he may be able to express to others, with precision, the results of his own experience and observation, or apply the results of the experience and observation of others to his own methods, or even to understand much that is written in books and papers on the subject of feeding animals, he must be able intelligently to make use of the terms, and apply the principles, which it is the object of this chapter to explain.

363. Nutritive Ratio.—The pupil will by this time under-

stand that any proper feeding-stuff, or ration, must consist of both nitrogenous and non-nitrogenous substance. Now, to compare one feeding-stuff with another, or one ration with another, it has been found convenient to make use of the *ratio of the digestible portion of its nitrogenous substance to the digestible portion of its non-nitrogenous substance*, and to speak of this ratio as the *nutritive ratio* for that particular feeding-stuff or ration.

The table in section 360 gives the *percentage of nitrogenous substance* in a number of feeding-stuffs. It also gives the *percentage of fat*, of the *carbo-hydrates other than fibre*, and of the *crude fibre*, all of which are non-nitrogenous. It gives, moreover, the percentage of the ash, and the percentage of water, that is, of the inorganic constituents of the food; but with these the nutritive ratio is not concerned. It further gives the *percentage of digesti-bility* under average conditions. Hence it gives sufficient information for the calculation of the nutritive ratio for any of the feeding-stuffs included in it. For example, take clover hay. Its nitrogenous substance is 11 per cent., of which 60 per cent. is digestible. Therefore, 6.6 is the percentage of its total digestible nitrogenous substance. Its fat is 3.2 per cent., of which 46 per cent. is digestible. Its carbo-hydrates other than fibre are 32.9 per cent., of which 66 per cent. is digestible. Its crude fibre is 29.9 per cent., of which 47 per cent. is digestible. Therefore, 1.47 is the percentage of its digestible fat; 21.71 is the percentage of its digestible carbo-hydrates other than fibre; and 14.05 is the percentage of its crude fibre. Adding these (see section 347), we see that 37.23 is the percentage of its total digestible non-nitrogenous substance. Comparing 6.6 with 37.23, we have the ratio 1:5.6, nearly, as the "nutritive ratio of clover hay."

364. Wide and Narrow Ratios.—The pupil should in this way find the nutritive ratio of a number of the other feeding-stuffs given in the table. He will find them to differ very much. For example, skimmed milk has the ratio 1:1.63; while mangels have the ratio 1:9.2. The first is said to be a "narrow ratio," the second a "wide ratio." A narrow ratio, as will be perceived, is one which indicates a feeding-stuff, or ration, comparatively rich in nitrogenous substance; and a wide ratio, one comparatively rich in non-nitrogenous substance.

365. The Value of Feeding Standards.—The value of a feeding standard lies in the fact that it presents, in a concise form, the conclusions reached by those who have had the time, means, and practical and scientific knowledge, necessary to make careful experiments with a view to ascertaining how feeding-stuffs should be combined in order to produce the best results. Moreover, the form in which the conclusion is expressed is one

which enables the feeder to compare the results of his own experience and observation with those expressed by the standards. It is not likely that, in his own practice, he will be able to make use of the same feeding-stuffs which the experimenters made use of in obtaining their results; but he will, nevertheless, know how to select his own fodders so as to embrace the same combination of nitrogenous substance, carbo-hydrates, and fat, and that is the main matter.

366. Feeding Standards not Absolute Guides.—It

must not be forgotten that a feeding standard is only to serve as a guide *in general;* it is by no means to be followed absolutely. The circumstances of individual feeders, with respect to the age and condition and habits of their animals, the range, quality, palatableness, and digestibility of their available feeding-stuffs, the prices of the same, the equipment of their stables for securing warmth, etc., are all so various that it would be impossible to establish rules that would be more than generally applicable.

367. Example of a Feeding Standard.—As an example of a

feeding standard, we will give one that has been found suitable for the sufficient maintenance of cattle at rest, that is, cattle neither doing work, nor laying on flesh or fat. The amounts are calculated per day, and per 1000 lbs. live weight:

FEEDING STANDARD FOR CATTLE AT REST.

(Calculated per day, and per 1000 lbs. live weight).

Digestible nitrogenous substance...................	0.7 pounds.
Digestible carbo-hydrates..........................	8.25 "
Digestible fat.....................................	.15 "
Total nutritive substance..........................	9.10 "
Total nutritive carbo-hydrates and fat.............	8.40 "
Nutritive ratio....................................	1:12
Total dry matter (organic) required................	17.5 "

368. Practical Observations.—The following observations are of-

fered:

(1) It will be noticed that the ratio is comparatively a wide one. The reason is that the animal is supposed to be neither working nor producing. In either of these latter cases, the ratio would have to be narrowed; that is, it would have to contain a much larger proportion of nitrogenous substance; moreover, the total amount of nutritive dry substance required would have to be considerably greater.

(2) The standard supposes a moderately warm stable. Exposure to cold would require the use of more carbo-hydrates as fuel-food.

(3) It will be noticed that the total amount of dry matter required by the standard (namely, 17.5 lbs.) is very considerably above the total amount of organic nutritive substance (9.1 lbs.). This implies that the fodder should be bulky, that is, that it should contain a considerable proportion of crude fibre; it may, indeed, consist of straw, with the addition of some hay.

(4) The quantities are calculated per day, and for an animal of 1000 lbs. Lighter animals would require less food of the same quality; heavier animals, more; but the variation is not in proportion to the diminished or increased weight. Smaller animals require, *in proportion*, more food than large ones, since the body surface of smaller animals (from which heat is lost by radiation) is relatively larger than in larger animals.

(5) The quantity of digestible *fat* is of no great importance where *mere maintenance* is required; but if *work* is necessary, or if *fattening* is to be secured, the object should be to increase the amount as much as safely can be done, in the one case, to produce heat easily, and in the other, that it may be absorbed into the body as body-fat; but as fat is apt to disturb digestion, care must be exercised in its use. The amounts given in the table in section 369 may be taken *as safe average quantities,* below which or above which it would not be prudent to go far.

(6) Should it be necessary to compound a ration to comply with the above standard, the feeder should make such a selection of his available feeding-stuffs as, in his judgment, will seem most likely to effect his purpose, and then should so proportion them that the total weight of their dry constituents, and the total weights of the digestible nitrogenous and non-nitrogenous substances contained in them, will correspond nearly with the figures there given. For example, suppose he has at hand oat straw and clover hay, and has reason to believe that their digestibility corresponds with the figures given in the table. By a little calculation, he will find that about 21 lbs. of these feeding-stuffs will give the requisite amount of dry matter, viz., $17\frac{1}{2}$ lbs. Then, by trial, he will make such a choice of the ingredients as will result in the nutritive ratio required, viz., 1:12. In working it out, he would perhaps happen to make choice of the combination, 15 lbs. of oat straw and 6 lbs. clover hay; but he would find that the nutritive ratio of this ration would be 1:13, which is too wide; that is, the proportion of non-nitrogenous substance to nitrogenous substance in the ration is too great. Finally, he would hit upon the proportion of 14 lbs. of oat straw to 7 lbs. of clover hay, which would work out as follows:

14 lbs. of oat straw would yield $14 \times \frac{85.7}{100}$ lbs. of dry matter, or... 11.998 lbs.

7 lbs. of clover hay would yield $7 \times \frac{83.3}{100}$ lbs. of dry matter, or... 5.831 "

Total dry matter in the ration...................... 17.829 '

Again—

14 ℔s. of oat straw would yield $14 \times \frac{4}{100} \times \frac{38}{100}$ of digest-

    ible nitrogenous substance, or....... ....   .2128 ℔s.

7 ℔s. of clover hay would yield $7 \times \frac{11}{100} \times \frac{60}{100}$ of digest-

    ible nitrogenous substance, or.....................   .4620 ''

Total amount of digestible nitrogenous substance in the   ———

    ration.................................... ....   .6748 ''

Similarly, the 14 ℔s. oat straw will yield:

Digestible fat.................................... ..   .08400 ℔s.

Digestible carbo-hydrates other than fibre............   2.09328 ''

Digestible fibre..............................   3.39038 ''

Total amount of digestible non-nitrogenous substance   ———

    in the straw ....   5.56766 ''

And the 7 ℔s. clover hay will yield:

Digestible fat....................................   .10304 ℔s.

Digestible carbo-hydrates other than fibre............   1.51998 ''

Digestible fibre....................................   .93371 ''

Total amount of digestible non-nitrogenous substance   ———

    in the hay....................................   2.60673 ''

Therefore the total amount of digestible non-nitrogenous

    substance in the ration........................ $= 5.56766$ ''

                                       $+ 2.60673$ ''

                                       $= 8.17439$ ''

And the *ratio* of digestible nitrogenous substance to digest-

    ible non-nitrogenous substance in the ration is as .6748 to 8.17439,

                                    or,   1:12, nearly.

It will thus be seen that the total amount of dry matter, and the nutritive ratio of this ration, correspond very closely with what is set down in the standard, and therefore may be adopted. It will be remembered that the above standard is calculated for an animal of 1000 ℔s. live weight. Smaller animals will require less, larger animals more, *in quantity;* but the *ratio* will, of course, remain the same.

[Note.—*To the Teacher:* The dry matter as here calculated includes the *ash*, while the dry matter as required by the standard should be all *organic.* The error, however, is not important here; nor would it be so in any case. If desired, it may be avoided altogether, by deducting from the amounts of dry matter as set down in the table for the various feeding-stuffs the respective amounts there set down as their ash.]

369. Table of Feeding Standards.—The following table gives a number of feeding standards that have been established in the way described in section 365. The standards are all calculated per day on the basis of 1000 ℔s. live weight. It will be noticed, however, that in the standards for cattle growing, sheep growing, and pigs growing and fattening, the average live weight which each animal may be supposed to attain to at various ages is also given; but of course these weights will vary greatly in actual experience. This table is given here that it may serve as a general guide to the pupil in his own practice as a feeder in after life;

TABLE OF FEEDING STANDARDS.

(Calculated per day, and per 1000 lbs. live weight).

	Total dry substance (organic).	Total digestible nitrogenous substance (albuminoids).	Non-nitrogenous substance. Total digestible carbo-hydrates, including fibre.	Digestible fat.	Total nutritive substance.	Nutritive ratio.
	lbs.	lbs.	lbs.	lbs.	lbs.	
1. Cattle, at rest in stall......	17.5	0.7	8.25	0.15	9.1	1:12
2. Sheep, producing wool (coarser breeds)..	20.0	1.2	10.6	0.2	12.0	1:9
Sheep, producing wool (finer breeds)....	22.5	1.5	11.75	0.25	13.5	1:8
3. Oxen, moderately worked..	24.0	1.6	11.7	0.3	13.6	1:7.5
Oxen, heavily worked.....	26.0	2.4	13.9	0.5	16.8	1:6
4. Horses, moderately worked	24.0	1.8	12.0	0.6	14.4	1:7
Horses, heavily worked....	25.5	2.8	14.6	0.8	18.2	1:5.5
5. Milch cows..............	24.0	2.5	13.1	0.4	16.0	1:5.4
6. Cattle, fattening (1st period)	27.0	2.5	15.75	0.5	18.75	1:6.5
" " (2nd period)	26.0	3.0	15.8	0.7	19.5	1:5.5
" " (3rd period)	25.0	2.7	15.6	0.6	19.0	1:6
7. Sheep, fattening (1st period)	26.0	3.0	16.0	0.5	19.5	1:5.5
" " (2nd period)	25.0	3.5	15.15	0.6	19.25	1:4.5
8. Swine, fattening (1st period)	36.0	5.0	27.5		32.5	1:5.5
" " (2nd period)	31.0	4.0	24.0		28.0	1:6
" " (3rd period)	23.5	2.7	17.55		20.25	1:6.5
9. Cattle, growing: Age in / Average live months. / weight per head.						
2- 3 165......	23.0	4.0	16.8	2.0	22.8	1:4.7
3- 6 325......	23.4	3.2	15.0	1.0	19.2	1:5
6-12 550......	24.0	2.5	14.4	0.6	17.5	1:6
12-18 750......	24.0	2.0	13.6	0.4	16.0	1:7
18-24 925......	24.0	1.6	12.5	0.3	14.4	1:8
10. Sheep, growing: Age in / Average live months. / weight per head.						
5- 6 62......	28.0	3.2	16.8	0.8	20.8	1:5.5
6- 8 74......	25.0	2.7	14.52	0.6	17.82	1:5.6
8-11 83......	23.0	2.1	12.1	0.5	14.7	1:6
11-15 91......	22.5	1.7	11.5	0.4	13.6	1:7
15-20 95......	22.0	1.4	10.9	0.3	12.6	1:8
11. Pigs, growing and fatten'g: Age in / Average live months. / weight per head.						
2- 3 50......	42.0	7.5	30.0		37.5	1:4
3- 5 110......	34.0	5.0	25.0		30.0	1:5
5- 6 137......	31.5	4.3	23.65		27.95	1:5.5
6- 8 187......	27.0	3.4	20.4		23.8	1:6
8-12 275......	21.0	2.5	16.2		18.75	1:6.5

370. Practical Remarks.—By an examination of the table, it will be seen that it confirms or explains many things that have been stated in the previous sections. We will here set down a few remarks which the table suggests, and also a few others of practical import.

(1) For the maintenance of animals at rest, the nutritive ratios are the widest. For example, the nutritive ratio for maintaining cattle at rest is 1:12, while for oxen, even moderately worked, the ratio is 1:7.5. Moreover, the dry matter of the ration in the first case is $17\frac{1}{2}$ lbs, while n the second case it is 24 lbs. A similar comparison may be made between cattle at rest and cattle producing milk, or fattening; and between sheep at rest and sheep fattening. For any kind of production, therefore, animals need both more food, and food of a more nitrogenous character, than when they are at rest; the additional *quantity* of food being required principally for the production of more heat, and the additional *nitrogenous* food for the production of tissue, or of muscular exertion. See sections 356, 329, 352, 354, and 359.

(2) Sheep require relatively more fodder than larger animals (see section 368 (4ᵖ). They also need fodder with a narrower nutritive ratio, both for maintenance at rest and in fattening. See paragraph 11, below.

(3) Horses and cattle working heavily require food with a narrower nutritive ratio (that is, food with a greater proportion of nitrogenous constituents) than horses and cattle working not so heavily. They also require more food (see section 359).

(4) Working oxen do not require food with so narrow a ratio as working horses, the reason being that they do their work *more slowly*, and are able to digest large quantities of bulky food, that is, food containing much crude fibre.

(5) From (8) and (11) in the table, it will be seen that swine eat, at first, much more food proportionately than any of the other animals, and that they increase in weight correspondingly. As they gain in weight, however, their consumption of food rapidly diminishes.

(6) It will be seen that while for animals at rest the amount of *fat* in the ration is not large, it must be increased very considerably for animals working or fattening; the reason being that, in the one case, heat is required, which the fat easily supplies; and in the second case, that the fat in the food conduces, both directly and indirectly, to the formation of body-fat (see section 344). For working horses, oats have always been found to be a most suitable part of their ration; and from the table in section 360, it will be seen that not only are oats rich in *nitrogenous substance*, but that the percentage of *fat* which oats contain is larger than that contained in any other of the cereal grains. Another reason why oats are so desirable for horses is, that in oats the food-nutrients are *highly concentrated*. The horse, unlike the ruminants, is but ill-fitted to digest a large bulk of coarse fodder. Hence, while he is fed hay, he needs oats also as a more concentrated food.

(7) For the production of wool, it has been found that all that is necessary is to keep the animals in good condition. The production of wool depends rather upon the breed of the animal, and upon the individual animal itself,

than on the food it eats. While a sufficiency of nitrogenous food is necessary to maintain the animal in good condition, more than this is waste, if wool be the sole object of the feeding.

(8) Cattle reduced in flesh and fat cannot at once be quickly fattened. They must first be brought into a well-nourished condition. In other words, an animal intended for fattening must already possess a sufficiency of both organized and circulatory protein (see section 330 (2) and (3)) before it is capable of rapidly storing up the protein and fat of the food as new fat.

(9) From the table, it will be seen that for the fattening of cattle the time has been divided into three periods. The first period begins when the animal is in the well-nourished condition, described as necessary in the preceding paragraph. This period has for its object (1) the checking of the oxidation and decomposition of the circulatory protein, which therefore becomes available to be deposited as permanent tissue; (2) the protection from oxidation of as much as possible of the fat in the food, thereby leaving it available to be deposited as body-fat; (3) the protection from oxidation of the fat already formed or deposited. Hence the nutritive ratio is comparatively wide. In the second period, the principal work of the fattening process is accomplished, and it is made as *rapid as possible*. This is effected principally by adding more nitrogenous substance to the food, without decreasing the amount of the non-nitrogenous substance. The nutritive ration is thus narrowed to the degree given, viz., 1:5.5; and experience has shown this to be the real fattening ratio, and, as such, suitable to be continued for some length of time. In practice, it is also usual, during this period, to replace some of the carbo-hydrates by an equivalent amount of fat substance (see table). In the third period, the nutritive ratio is widened a little, for the purpose of increasing the palatability of the food, and so inducing the animals to eat more of it. This is generally effected by the addition of roots to the ration.

(10) In the practice of fattening animals, the preparation of the fodder is of course important, since in this way the fodder may be made more palatable, and the animals be induced to eat more largely of it. But it should be remembered that this preparation of the food does not influence the absolute digestibility or nutritive value of it. It, to increase the palatableness of food, salt is added to it, care should be taken that the quantity be not too large (see section 335). Similarly, care should be taken that the fodder be not made too watery (see sections 336 and 349). The food for sheep should be less watery than that for cattle.

(11) By reference to the table, it will be seen that sheep require a more nitrogenous food in order to produce fattening than any of the other animals. They can bear a more concentrated fodder than cattle, and, as was said in the last paragraph, their food should be drier. Hence roots, which are always very watery, are somewhat less beneficial to sheep than to cattle.

The time required for fattening sheep has been divided into two periods, and these correspond to the first and second periods for cattle; but before the

fattening process commences at all, the animals should be in a well-nourished condition. Sheep fatten more rapidly after being shorn than when carrying their wool; the explanation seems to be that the animal's appetite becomes better when freed from its wool.

(12) As said in paragraph (5), swine eat, at first, more largely, increase in weight more quickly, and also fatten more quickly, than other animals; but in these respects their ability rapidly diminishes as the fattening process goes on. Hence the time required for their fattening has been divided into three periods, as will be seen from the table. And it will be further seen that, as the fattening process goes on, the nutritive ratio is widened (thus preventing unnecessary protein consumption), and the quantity of food allowed per day is lessened. Widening the nutritive ratio has the further effect of making the fat deposited firmer and of better quality.

Of late years, the popular demand is for bacon and pork, in which the proportion of lean meat to fat meat is greater than formerly, and the fat and lean are required to be well intermixed. Hence it is probable that, to produce meat of this character, the fattening process must not begin so early as used to be the case, and that more nitrogenous food must be given than the table indicates.

(13) The nutritive ratio for the food of milch cows is comparatively narrow. The explanation is, that nitrogenous substance (protein) is necessary for the production of the dry substance of the milk (see section 354); and that, within certain limits, the percentage of dry substance will be increased with an increase in the supply of nitrogenous substance in the food. But the quantity of nitrogenous food supplied must not be enough to induce undue protein consumption, which of course would be waste.

(14) It will also be noticed from the table, that the quantity of fat in the standard ration for milch cows is less than in the rations for fattening. As a matter of fact, the fat of the ration seems to have but little effect upon the milk production. Apparently, it does not increase the percentage of fat in the milk; but it does slightly increase the quantity of milk, by protecting some of the nitrogenous substance of the food from oxidation, and thereby increasing the amount available for the formation of cells in the milk-glands (see section 353); that is, it seems to increase all the ingredients of the milk, not the fat only. But this fact is not quite fully established.

(15) From an examination of (9), (10), and (11) in the table, it will be seen that for all *growing* animals the nutritive ratios are narrow, and that the younger the animal is, the narrower is the ratio. This corresponds with everything that has been said in the earlier sections of this chapter; namely, that for the development of all the important parts of the animal organism, nitrogenous food is absolutely essential; that is, an excess of protein must be supplied to the animal over and above what will be oxidized and excreted, and that the development of the animal in almost all its parts must be accomplished out of this excess.

(16) The nutritive ratio of milk, as will be found from the table (section

360), is about 1:2.5. And it will be noticed that this is much narrower than the narrowest ratio set down as suitable to growing animals; while it is known to everybody that milk, by itself, forms a suitable ration for all young animals. The explanation is, that the youngest animals (to which milk is usually given) need so much nitrogenous substance for the upbuilding of the tissues of their rapidly growing organism, that they are able to make use, without waste, of all the nitrogenous substance contained in the milk supplied them, comparatively large though it be.

(17) If the pupil will refer to the last column but one in the table, and examine that part of it which appertains to cattle growing, sheep growing, and pigs growing, he will notice that *the amount of total nutritive substance set down as being required for each age given per 1000 lbs. live weight decreases quite rapidly with the age of the animal.* This is due to the fact that *the increase in weight per month also decreases with age,* as may be easily seen by a little calculation. This is a fact that should be carefully borne in mind. The more rapid gain in weight at first is largely due to the greater power which the young animal possesses of storing up in its body, as stable tissue, the nitrogenous substance supplied to it in its food; although it is *partly* due to the greater quantity of water which is contained in the apparently solid substance of young animals. The fact, however, is of gre.t importance to the feeder, for from it will be seen *the wisdom of securing, during the whole time of the animal's development, the largest gain of flesh and fat that is consistent with economy.*

THE INORGANIC NUTRIENTS.

371. The Inorganic Nutrients: How Their Deficiencies are Supplied. —It was stated in section 323 that, with the exception of common salt, the inorganic (or mineral) nutrients are generally present in all the ordinary feeding-stuffs and rations in sufficient quantities; and that therefore no special care need be taken to supply them. But it occasionally happens that the mineral nutrients have to be specially supplied. The more important mineral nutrients are lime, phosphoric acid, and potash (the principal mineral constituents of bone—see section 316), and chlorine and sodium, the elements of common salt. The necessity of a due supply of *salt* is, however, generally understood, and the want supplied. *Potash* is contained in sufficiency, and oftentimes in excess, in all the ordinary feeding-stuffs. *Lime* and *phosphoric acid,* on the other hand, though generally present in most fodder-rations, are sometimes deficient, and then the deficiency should be specially supplied.

Grass and hay, and particularly clover grass and clover hay,

are quite rich in lime, but comparatively poor in phosphoric acid. The same is the case with pea straw. The cereal straws have an excess of lime, but are lacking in phosphoric acid. On the other hand, the roots, though they have little ash in all, contain more phosphoric acid than lime ; and the grains are all rich in phosphoric acid, and poor in lime.

Hence, animals which are fed largely on grass, or on coarse fodders, as hay, pea straw, or the cereal straws (as cattle often are), although they get more than enough of lime, do not get enough of phosphoric acid ; or, as the phrase is, they suffer from "bone hunger." On the other hand, animals fed largely on grain and roots (as, for example, pigs often are) lack lime. To supply the deficiency of phosphoric acid, *bone meal* (that is, pure bone reduced to powder) is sometimes given ; though its use is not without danger, since diseased bone may sometimes be present. To supply the deficiency of lime, *chalk* (which is carbonate of lime) or *leached wood ashes* are given. But, whenever possible, both these deficiencies should be made good by the feeding of mixed foods which correct one another.

CHAPTER XIV.

The Feeding, Care, and Management of Horses, Cattle, Sheep, and Swine.

372. Preliminary Remarks.—The preceding chapter was intended to give the pupil, and especially the older pupil, some acquaintance with the *scientific principles* upon which the processes of feeding depend. In this chapter, we shall offer some practical remarks which will be found in harmony with the scientific conclusions therein set forth, but which will be purposely expressed in untechnical language, simple enough for even the youngest pupils to understand ; for it is important that any one intending to make his living by farming, no matter how

early he may leave school, should have at least such an acquaintance with the principles and practices of feeding as may be obtained from the study of this chapter.

373. The Effect of Food Upon the Age of Maturity.
—By *the age of maturity* is meant the time at which animals reach their full development. In feeding, *early maturity* means the completion of the processes of growth in the shortest period consistent with full and healthy development. This period may be much shortened by judicious feeding. Feeding in such a way that growth will be continuous as well as rapid hastens maturity. It may be added, also, that breeding from parents with early maturing tendencies has the effect of transmitting these tendencies to the offspring.

374. Law of Animal Development.—It is a law of animal development that the further the animal gets from birth the smaller is its gain of substance per day, and the greater is the amount of food required to produce a pound of flesh or fat. (See also section 370 (17).) But, because of inattention to this law, thousands of dollars are lost by the farmers of Ontario every year. Feeding for meat production (except in the case of milking cows or working oxen) yields but little profit (if, indeed, it yields any) after the animal is matured. Hence the object of the feeder should be to obtain as great a gain as possible during every part of the period of the animal's immaturity. *The food fed to growing animals in winter in quantities too small to increase their autumn weights is, in nearly every case, wasted.*

375. Conditions Affecting the Benefits of Feeding.
—The benefits to be obtained from feeding animals depend not only on the quantity and composition of the foods with which they are fed, but also and to a large extent upon their breed, habit, and condition, on their surroundings and the care taken to make them comfortable, and on the attention which is given to the selection and preparation of their food. We here offer some practical remarks on these points:

(1) *Influence of breed, disposition, and condition.* Animals that, whether from their breed or from individual disposition, are slow to mature, are unprofitable for the production of meat,

since they do not make good use of their food; similarly, animals which are unable to give a good quantity of fairly rich milk, are unprofitable for dairy purposes. A similar remark applies to sheep intended for the production of wool. The disposition to lay on flesh, or that to produce milk, or wool, or work, are all natural tendencies, which are generally peculiar to different breeds, and are affected only in a minor degree by feeding. Hence is seen the importance to the farmer of obtaining possession of animals of the best breeds. The common unimproved stock of this country will not give returns of meat, milk, wool, or labor, equal to what may be obtained from improved stock, even with the same food, or with no greater care or attention in feeding.

(2) *Influence of surroundings and comfort.* The winters of our country are so cold that every sort of stock kept needs protection from the weather. Therefore, warm stabling in winter is of the greatest importance. Food is the dearest kind of fuel to use in keeping animals comfortable. (See section 356.)

(3) *Influence of attention in the selection and preparation of food.* As this subject embraces many details, it will be more convenient to treat it, along with other matter, in the remaining sections of the chapter.

FEEDING, CARE, AND MANAGEMENT OF HORSES.

376. Treatment of Foals before Weaning.—Opinions are divided whether autumn or spring is most desirable as the time at which the foals should be born. If the foals are born in the spring, the food at hand, namely, tender grass, is more suitable than that which they could obtain at any other season; while, on the other hand, if the foals are born in the autumn, they naturally can be better cared for in the winter while the dam is at liberty to rest from labor than in the spring or summer.

When a day or two old, the young foals may need one or two ounces of linseed oil, or castor oil, to regulate their digestion.

They should be weaned when five or six months old, but before complete weaning, they should have learned to eat grain along with the dam.

377. Treatment of the Foals after Weaning.—After weaning, the foals, during their first winter, should get a liberal supply of food. This may consist of hay and oats. The oats may be either bruised or whole, and should be given twice or thrice a day. The evening meal is improved by adding bran; and if a small amount of ground or boiled flax seed be added, the digestion of the whole will be aided. The skimmed milk of cows, when obtainable, makes a suitable ration for foals after weaning. [It will be noticed that, as stated in the previous chapter, the food most suited to young, fast-growing animals is highly nitrogenous.]

For the second winter, the food should be much the same as for the first; but it should, of course, be increased in quantity. Potatoes or roots (easily digestible and appetizing carbonaceous foods) may sometimes form part of the evening meal. Various other changes may be made in the diet, as experience may warrant.

Foals in winter should be kept in loose box-stalls, with access to open sheds or paddocks in time of fair weather, in order to enable them to take sufficient exercise. Before being weaned, they should be broken to the halter, in order to render them docile, and by the end of the second winter they should have been taught to drive.

378. Treatment of the Dam.—The dam may be worked moderately nearly all the time prior to the birth of the foal, if the working be done with due care. While she is suckling the foal, liberal feeding (with nitrogenous food) is required. The food may consist of hay, and a mixture of bran, bruised or ground oats, and barley, in the proportions of 2, 2, and 1. To this should be added, for the sake of aiding the digestion, a small amount of ground flax seed. Hay and unground oats, with some ground linseed, also make a good ration; so also does nutritious grass alone, though the latter is improved by the addition of oats. [The pupil who has read the preceding chapter will notice how all these rations conform with the principle laid down in it; namely, that for the production of new tissue—for it must be remembered that the foal's food supply depends upon that of its mother—nitrogenous food is required.]

379. The Treatment of Working Horses.—If horses are kept for the production of work, their food must be, first, such as will maintain their muscular system in good condition, and, second, such as will produce the heat necessary to supply their muscular system with the energy required to do their work ; for it must be remembered that an animal doing work requires heat to supply the energy necessary to accomplish the work, just as much as a steam-engine, or other machine, that is kept working by heat. Hence, *both muscle-sustaining and heat-producing foods* are necessary (that is, both nitrogenous and carbonaceous foods) ; and since the horse is not furnished (as the ox or sheep is) with a digestive apparatus enabling it to extract nutriment easily from large quantities of comparatively coarse fodder, it follows that the food for working horses should be, at least a considerable proportion of it, *concentrated food*, such as some of the grains. But, on the other hand, as the grains, if fed alone, are disturbing to the digestion, it follows that *coarse fodder* must form a part of the ration. For this purpose, hay is the best fodder obtainable, and from 25 to 40 per cent. (by weight) has been found a proper proportion of it to use. The grains to be used are oats, barley, and corn ; of which oats are the best, being the richest in muscle-producing, muscle-sustaining nutrients, and being also fairly rich in heat-producing nutrients. Some feeders think it necessary to cut the hay and grind the grain, and after mixing the food thus refined, to slightly damp it before feeding, as this causes the meal to adhere to the hay. If the food be thus prepared, a part of the ration may very advantageously be made up of good straw. [The advanced pupil should carefully read sections 355, 359, 329, and 361 (8) of the preceding chapter.]

THE FEEDING, CARE, AND MANAGEMENT OF BEEF CATTLE.

380. Importance of Good Ancestry.—Cattle intended for the making of beef should come of ancestry which have shown their ability to take on flesh readily, and to mature early. The sire, at least, should have been well and purely bred. When thus descended, they are pretty sure to inherit the good qualities of their ancestors, and to show themselves good and profitable feeders.

381. Treatment of Calves: General Remarks.—
For the purpose of producing beef, autumn calves are most in
favor; the reason being that during their first winter, when they
most need care and attention, the farmer has more spare time to
look after them than at any other season, and that by the time
their second winter comes they are sufficiently developed to endure
it easily. Moreover, the autumn calves can be got ready for
shipping, or for the butcher, when only about thirty months old,
while spring-born calves require the full three years.

382. Treatment of Calves Raised on the Dam.—
When the calf is raised on the dam, it is usually kept for the first
year in a loose box-stall in the stable. In time of flies, the stall
(or stable) ought to be kept darkened. For the first few days
after birth, the dam should be allowed to remain with her
offspring; but after that, she should be allowed in with it only
three times a day: then only twice a day; until finally, for a
while before weaning time, she should be allowed in only once a
day. Weaning should take place at about from five to seven
months from birth.

When about six weeks old, the calf should be fed some bran
and ground oats. When it has learned to eat this sort of food
freely, it should get, for some months subsequently, all it will eat
up clean of ground or unground oats; or of bran and ground peas:
or of bran and ground barley; or of a mixture of these; but the
flesh-producing (or nitrogenous) foods, as bran and oats, must form
the main portion of the mixture, or else the animal will lay on
fat at the expense of more important development. If a little
oil cake or flax seed be added, it will aid digestion. A liberal
supply (in winter) of sliced field-roots, or (in summer) of ensilage,
with cut green-food, is helpful, being both appetizing and
nourishing. The prominent idea should be, as in the raising of
all young stock, *pushing right ahead all the time in the develop-
ment of necessary flesh and bone, without the production of too
much fat.*

383. Treatment of Calves Raised on Skimmed Milk.
—Calves intended to be raised on skimmed milk should be fed
by hand with new milk until they are from three to six weeks

old. Then a little skimmed milk should be used in place of a part of the new milk, the proportion of the skimmed milk being gradually increased until the new milk is no longer necessary. This transition period should occupy about from one to three weeks' time. To each meal's supply of skimmed milk, there should be added a half tea-cupful of flax-seed, previously prepared by being soaked in water several hours, and boiled or scalded one hour. It should be mixed with the milk while warm. Not only does the heated flax-seed serve to warm the milk to a suitable temperature, but its fatty substance supplies the place of the cream that has been removed from the milk. The quantity of flax-seed thus prepared may be increased as found needful. As the calf increases in age and development, other foods must be given, similar to those described in the previous section.

The method of raising calves here described is now thought to be the most profitable. Water and salt should always be at hand in the feeding of all young stock, so that they may supply their needs at will. It should be remembered that the treatment of cattle intended for beef should at all times be liberal.

384. Treatment of Beef Cattle During the Second and Third Winters.—During the second winter some straw may be fed, but it should always be previously cut. The supply of grain should be moderate, and of roots, plentiful.

During the third or finishing winter, the food should be given with more and more reference towards the production of fat as the season progresses. The following grain and cut-feed rations will be found suitable:

(1) Equal parts, by weight, of bran, oats, barley, and peas, ground into meal, and fed with cut-feed.

(2) Equal parts of ground oats, ground peas, and oil cake, mixed with cut-feed.

(3) Equal parts of ground oats, ground barley, and ground peas, and 2 lbs. of oil cake, daily, mixed with cut-feed.

(4) Equal parts of oats, barley, and peas, ground into meal, and mixed with corn ensilage.

No fixed general rule as to the quantities of the above

combinations of ground grain and oil cake that should be mixed with the cut-feed can be given; for some animals will make use of more than others. But about 1 ℔. of grain-meal, daily, to every 100 ℔s. live weight may be set down as a fair average. The animals should never be fed more than they will eat with relish. In addition to the above, they should also receive from one to four pecks of roots per day. If possible, these should be pulped, and fed along with the cut-feed.

[The student who has read the previous chapter will notice (1) that all the foods recommended are put in as digestible a condition as possible before being fed; (2) that the foods are, for the most part, concentrated foods, consisting largely of grains, oil cake, and roots; (3) that the grains are chosen so as to secure a large proportion of nitrogenous nutrients; (4) that the oil cake used adds very largely to the nitrogenous complexion of the food; (5) that the cut-feed supplies not only the bulkiness which ruminating animals require in their fodder, but also a considerable proportion of the needful carbo-hydrates; and (6) that the roots recommended give an additional supply of carbonaceous nutrients, and these, too, of a very digestible sort, while they have the further merit of stimulating the appetite of the animals for all their food.]

385. Treatment of the Dams.—The dams should be kept in fair condition only; very much fat is injurious. While suckling their calves, the supply of food should be abundant, nutritious, and of a character to produce much milk (that is, it should be largely nitrogenous—see section 354); before this period, it should be of the same general character, but possibly not so abundant.

THE FEEDING, CARE, AND MANAGEMENT OF SHEEP.

386. Preliminary Remarks.—In this country, sheep are usually grown for the production of both wool and mutton, and not as a main industry of the farm, but rather as a minor industry; although perhaps no country in the world is naturally better suited to the raising of sheep than many parts of Canada. Moreover, on every average one-hundred-acre farm in our

country about a dozen sheep may be fed in summer on the odds and ends of the pastures, without interfering with the usefulness of the farm for all other purposes. Clay lands, since their pasturage is both rich and strong, are those best adapted for growing the heavier breeds of sheep.

387. Treatment of the Lambs.—February and March lambs are the most suitable for the show-ring; but for ordinary uses, April or May lambs are quite as suitable, and these are more easily reared, by reason of the milder weather of their season, than those born at an earlier date. Early lambs are to be preferred, if they and their dams are soon to be sold for meat, for then the dams will have opportunity to become fat on the tender nutritious grass of spring and early summer. For early lambs, warm lambing-pens are a necessity. If a young lamb is chilled, dipping it in warm water, and rubbing it dry with a cloth, may restore it.

When two or three weeks old, the lambs should have access to some ground oats, or a little ground peas and bran, which they may eat at will, but to which the dams cannot come.

The lambs may be weaned when about five months old. They should then be put upon good pasture, and receive, at the same time, in a trough placed in the field, a ration of about ½ ℔. oats, ¼ ℔. bran, and ¼ ℔. oil cake, per day—more or less, according as they are intended to be sold to the butcher in the autumn, or kept over winter for feeding purposes.

388. Treatment of the Dams.—The dams require most liberal feeding while suckling their young, but only nutritious food in moderate quantities before this period. Except during stormy weather, they should have access to a yard at all times at will.

Prior to the birth of the lambs during early winter, pea straw, cut early and well cured, does well for the morning and noon meal, and alsike clover, fine and tender, for the evening meal. If to this there be added, for each sheep, 2 ℔s. or less per day of sliced roots, the appetite will be improved, and tone will be imparted to the digestive organs.

Subsequent to the birth of the lambs, after the first few days,

the dams should get nearly, but not quite, all they will take of oats, peas, barley, and bran; or of oats, peas, and bran; or of oats, barley, and bran; together with some oil cake. And even when they are turned out on pasture, this grain and meal ration should be continued for a time, for the purpose of counteracting the laxative influence on the digestive organs of the tender grass.

[The student who has mastered the previous chapter will notice that the foods recommended for the dams are all highly nitrogenous in their composition; but that those recommended for use before the birth of the lambs are not so concentrated as those recommended for the subsequent period. It will be seen, also, that in recommending the pea straw to be cut early, the object is to secure it as highly nitrogenous in character as possible. See section 361 (5).]

389. The Treatment of Sheep while Fattening.—As a rule, none but sheep born the previous spring can be profitably fattened in the winter. These should be fed a mixture of peas and oats; or of peas, oats, barley, bran, and oil cake; or of peas, bran, and oil cake; or of barley, bran, and oil cake. These foods are thought by some feeders to give much more satisfactory results if the grain is ground, and the mixture fed with cut-hay. The addition of sliced roots is also beneficial, though, since roots are very watery in their composition, they are less suitable for sheep than for cattle. But though to secure the best results in fattening the food for sheep should not be too watery, yet they should at all times have access to an abundance of pure water for drinking purposes.

THE FEEDING, CARE, AND MANAGEMENT OF SWINE.

390. Preliminary Remarks.—Swine-breeding must always receive some attention on every well-ordered farm, for there is much food produced on a farm that can be more profitably fed to swine than to any other animals. Moreover, swine-breeding, when pursued as one of the main industries of the farm, can be made very profitable.

391. Treatment of Young Pigs: General Remarks. —Spring litters are, on the whole, preferable to autumn litters,

since the summer season, with its warm temperature and tender grass, is a more suitable time for raising young pigs than the winter season. As soon as the young pigs are able to drink it, they should have access to skimmed milk; but this should be placed where the dam cannot reach it. After a time, oat-meal should be added to the milk. The pigs should be weaned when from six to eight weeks old. After weaning, skimmed milk, to which some wheat middlings or ground oats are added, is the best food that they can get. The skimmed milk is, in so far as its dry substance is concerned, just the sort of food that the young pigs require; but so large a percentage of it is water, that it needs to be supplemented by the meal.

392. Treatment of Spring Litters.—It is good for spring litters to have, along with their other food, the run of a pasture on which they may feed at will. But if it is necessary to keep them in a pen, there should be a yard attached to it, in which they may run and feed at will; and green-food, such as clover or green peas, should be cut and mixed with the meal given to them there, in order to supply the place of pasture.

393. Treatment of Autumn Litters.—For autumn litters, access to a barn-yard in winter is beneficial, as this encourages them to take exercise. Abundance of bedding is required, and care should be taken to change it frequently; this is necessary to prevent dampness, which has often the effect of crippling the limbs. In addition to skimmed milk, they should be supplied with meal (wheat middlings, ground oats, etc.) and roots. Meal and roots together are better than meal alone.

394. Treatment of Pigs while Fattening.—In fattening pigs, the following remarks will be found applicable:

(1) The pens should be kept at an even temperature of not less than 45°.

(2) Of the food intended for them, the pigs should get all they will eat clean, but not more.

(3) Foods conducive to fat production of course must be supplied; of these, peas (which are highly nitrogenous) and corn (which is not so nitrogenous, but consists largely of very digestible carbo-hydrates and fat) have been found the best. Perhaps

a combination of these two would be more suitable than either of them alone.

Peas, oats, and barley, ground with meal, and mixed in the proportions of 2, 1, and 1, constitute a good ration; but many others might be named that would, perhaps, be equally useful.

395. Curing Pork.—The following remarks concerning the curing of pork for home use will be found practically useful:

(1) The killing should be done when the weather is cold, and the carcass should be allowed to stiffen before it is cut up for salting.

(2) But, before it is cut up, the carcass should not be allowed to become frozen through, or it will not readily take in the salt.

(3) When the carcass is cut into pieces, sprinkle salt on a clean floor in the cellar, or on a temporary table of planks or boxes arranged there, and place on it a layer of the pieces.

(4) Then to each of the pieces apply powdered saltpetre, at the rate of 2 or 3 ounces to every 100 lbs. of pork, and follow this with a thick layer of salt. Then lay down a second layer of pieces, and apply saltpetre and salt as before. Proceed in this way till all the pieces are taken.

(5) In about ten days repeat the salting process, but without using saltpetre. Then allow the pork to remain in the salt for from four to six weeks, according to the thickness of the meat.

(6) When this stage is completed, brush or wipe off the salt, and hang the pieces in the kitchen, near enough to the stove to quickly produce a dry skin. When this is formed, remove the pieces farther from the stove, and allow them to hang until they are thoroughly dry.

(7) Then hang them for storage in a cool, dry place, from which all flies are kept away.

CHAPTER XV.

Breeding.

396. Every Breeder Should Aim at Realizing a Standard of Excellence.—When breeding is pursued with-

out a definite object in view, the chances are that the results will be unsatisfactory. The successful breeder is one who fixes in his mind a standard of excellence which, in all his efforts towards improving his stock, he aims to realize. That is, he keeps steadily in view an ideal animal possessing the qualities, whether of character, or of form, or of action, color, etc., that he desires to produce, and he directs his energies accordingly. This ideal must, of course, be in harmony with the general characteristics of the breed of animals engaging his attention, but none the less it should be a high ideal. In this way, the breeder's own stock, and the general stock of the country, are both improved.

397. "Like Begets Like."—It has long been an observed fact in breeding that "like begets like"; that is, that the peculiarities of parents are likely to appear in their offspring. It follows, then, that when parents are chosen whose form, appearance, qualities, disposition, etc., are those desired by the breeder, there is considerable probability that their offspring will be similarly characterized. The breeder, therefore, who, possessing a high ideal, wishes to realize it, will select, as the parents of his future stock, animals that conform to his ideal. In other words, he will "breed only from the best."

398. Spontaneous Variation.—But it must be noticed that the law of transmission stated above, namely, that "like begets like," is *true only in a general sense.* Were it universally true (that is, true without exception), every animal would be like its parents, and the improvement of live-stock would be impossible. But observation of the animal kingdom shows us that offspring very frequently differ from their parents (sometimes, indeed, from all their ancestry), not only in color, form, habit, disposition, etc., but also in the development of their various organs, limbs, etc., and in their bodily powers, and in the uses to which these may be put, and so on. And, moreover, these differences may be very considerable. This tendency of animals to be unlike their parentage is called *spontaneous variation.* Like the principle of heredity implied in the phrase "like begets like," spontaneous variation is a law of nature; but it is a law that is little understood beyond the fact that it is in constant manifestation.

399. Relative Strength of the Two Laws.—The law that "like begets like" and that of "spontaneous variation" are characteristics of the whole animal kingdom ; but the laws are, to some extent, mutually opposed to one another, and whether, in any particular case, one or the other is the stronger, depends largely upon the character of the ancestry. In animals whose ancestors for many generations back have been more or less of one uniform type (as, for example, in animals of pure breed—see section 401, or animals that live in the state of nature), the law that "like begets like" will be strong, and the tendency to spontaneous variation will be comparatively weak ; but, on the contrary, in animals whose ancestors have been of many differing types (as, for example, in the ordinary unimproved breeds of domestic animals), the law that "like begets like" will be comparatively weak, and the tendency to spontaneous variation will be strong.

400. Atavism.—There is another peculiarity of descent which may be mentioned. Offspring frequently resemble in features, disposition, or otherwise, the ancestors of generations back, sometimes of many generations back. This tendency to reproduce suddenly the characteristics of ancestors is termed *atavism*, or *reversion*. Although apparently a natural law, it is not very well understood. We have an illustration of it in the "scurs," or little horns, which appear sometimes, though rarely, in Galloway cattle, although these cattle have been bred pure without horns for centuries. It should be remarked that often-times it is impossible to distinguish between reversion and variation.

401. Pure-Bred Animals.—Pure-bred animals are those which are of certain distinguishing characteristics, and have been bred for a long time from animals of the same characteristics, without admixture with animals of different types. It follows, therefore, that animals which are of pure breed naturally resemble one another in color, form, habits, disposition, and available uses, and, moreover, that in them the law that "like begets like" is strongly manifested. Hence, the longer the period during which a breed has been bred pure, the more certainly will its individual animals transmit the peculiar

characteristics of the breed to their descendants. For the pur-
pose, therefore, of improving common stock, none but animals
of pure breed should be chosen, because no others are so likely
to transmit their excellences to their offspring; that is, none
others are so "*prepotent*," as the phrase is. On the other
hand, it must not be forgotten that animals of pure breed are
more likely than any of the others to transmit their *defects* to
their offspring.

402. How Live-Stock is Improved.—When a breeder
wishes to improve his stock, he selects as sire and dam animals
that, in their various characteristics, conform as closely as
possible to his ideal. By reason of the law that "like begets
like," he trusts that the offspring of this pair will, with respect to
the characteristics desired, resemble their parents. But he
knows, also, that the tendency to spontaneous variation will very
likely interfere with this wished-for resemblance. So that in all
probability it will happen, that while some of the offspring will
resemble their parents closely, others may show the desired
characteristics even in a higher degree, and others again in a less
degree. But whatever the variation may be, he will select, as
future sires and dams, out of the several descendants, only those
individuals whose characteristics conform most closely to his
ideal. In this way he will proceed, *always selecting the offspring
likest his ideal, and rejecting all others*, until his whole stock is
strongly marked by the characteristics he has been aiming to
realize.

403. Importance of Pure-Bred Sires.—In case the
breeder, when beginning to improve his live-stock, cannot secure
both a sire and a dam that conform to his ideal, he should at
least secure a sire that conforms to it. In other words, he
should use pure-bred sires in all his breeding operations, and, if
possible, he should always use sires of well-known *prepotency*;
that is, well-known for their certainty in transmitting their
qualities to their offspring. The offspring of a pure-bred sire,
and a dam not of pure-breeding, are more likely to resemble the
sire than they are the dam; and especially is this true if the sire
is known to be prepotent. Again, the offspring of such of these

as are dams, *if their sires are pure-bred*, are still more likely to resemble the sires than the dams; that is, if the sires have been chosen for their conformity to the ideal type. Hence the continued use, in stock-breeding, of pure-bred sires is obvious. But, as far as possible, *both sires and dams* should all be selected for their close conformity to the ideal, for the work of long years of improvement may be destroyed at any time by one careless selection. However, it should be observed, that since in actual practice it is impossible to secure both sires and dams that are alike excellent in every particular, it has been found most advantageous to select individuals that have certain points closely conforming to the ideal and pair them with those that conform as closely as possible to the ideal in other points.

404. Herd Book.—A "herd book," "herd record," or "herd register," is a book in which the birth and lineage of the individual animals of a breed are recorded for reference. Sometimes other facts are recorded, as speed, in the case of trotting or running horses, and milk or butter production, in the case of dairy cows. The lineage of animals thus recorded is what is understood by the term *pedigree*. To defray the expense of keeping these records, and otherwise to promote the interests of the breeds which they record, the breeders of the different varieties of stock generally join together and form *associations* or *societies*. These are usually designated by the breed they represent.

405. Terms in use Respecting Lineage.—In speaking of the lineage of animals, certain terms are in common use, such as "thorough-bred," "pure-bred," "cross-bred," "grade," and "high-grade." The term *thorough-bred* properly applies to the English race-horse, and should be restricted to that use; but it is often used loosely in the sense of "pure-bred." A *pure-bred* animal is one descended on both sides from animals belonging to any one of the recognized pure breeds. A *cross-bred* animal is one that is the offspring of parents of two distinct pure breeds. A *grade* is the offspring of parents one of which is pure-bred, and one of which is not. *High-grades* are animals of mixed breeding, in which the blood of pure-bred ancestors largely predominates.

406. Practical Remarks Respecting Breeding.—(1) It is a great mistake to rear animals from parents that are of inferior merit, simply because they are of pure breed; for such parents are the more likely to transmit their defects to their offspring, for the very reason that they are of pure breed. (2) In all stock-breeding, the breeder should aim at developing useful qualities, rather than those that are fanciful. (3) Good blood and good breeding are of no avail as against improper methods of feeding, care, and management.

CHAPTER XVI.

The Breeds of Live Stock.

HORSES.

407. Principal Breeds.—The principal breeds of horses in Canada at the present time that are bred pure are the Thorough-bred, the Standard-bred, the Cleveland Bay, and the Hackney, among horses that are bred for speed and action; and the Clydesdale, the Shire, the Percheron, and the Suffolk Punch, among those that are bred principally for their strength in drawing burdens. The Thorough-bred is distinctively a *running-horse;* the Standard-bred is a *trotting-horse;* the Cleveland Bay and the Hackney are *carriage horses;* while the Clydesdale, the Shire, the Percheron, and the Suffolk Punch, are *draught horses.*

Race Horses.

408. The Thorough-bred Horse.—The Thorough-bred is the oldest and best established of all the breeds of horses. It is sometimes called the "blood-horse," by reason of the long period of time through which its purity of blood may be traced. It is no doubt descended from the oldest English breeds, but in its blood have been infused both the blood of the heavier horses of Europe, and that of the lighter and more graceful oriental races, especially the Turkish and the Arabian. Indeed, the

Thorough-breds of to-day all trace back to three Turkish or Arabian horses imported into England in the reign of William III. The Thorough-bred is distinguished for its lithe, willowy form, its clean-cut limbs, its fine skin and hair, and its intelligent eye. Its speed, resolution, and endurance, are most remarkable; but it is usually excitable and nervous in temper, and is sometimes lacking in docility. It is used principally as a running horse on the race-course; and having been for so long a time (at least, more than two centuries) bred for this purpose, it is but ill-adapted for work requiring slow and steady movement. However, it has been of great benefit in improving the quality of other breeds of horses, not only in England, but in every other part of the
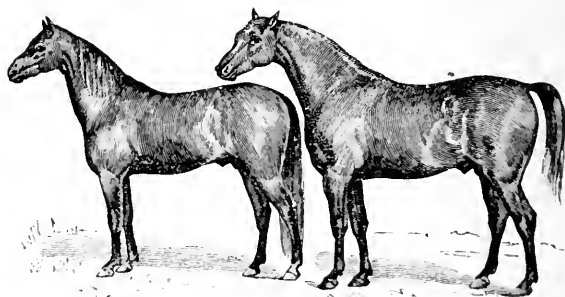
Fig. 28. Standard-bred Horse.   Fig. 29. Thorough-bred Horse.

civilized world as well. All the trotting horses, carriage horses, and roadsters of to-day that are of good merit, possess in a greater or less degree some of the blood of the English Thorough-bred.

409. The Standard-bred Horse.—The Standard-bred horse owes its origin to the general fancy for speed at the trotting gait which prevails over this continent. Standard-bred trotting horses are as remarkable for speed in their own peculiar gait as the Thorough-breds are for speed in running. The Standard-breds are entirely of American development, but are largely of Thorough-bred blood, many of them having descended from an English Thorough-bred horse named *Messenger*,

imported into the United States in 1788. The Standard-breds
resemble the Thorough-breds in general appearance, but they
are not so tall, nor so "rangy." Like the Thorough-breds, they,
too, have been instrumental in improving the common stock of
the country.

Carriage Horses.

410. The Cleveland Bay.—It is only comparatively
recently that the Cleveland Bay has been considered a pure
breed; although in the district adjacent Cleveland, in York-
shire, England, horses somewhat resembling the recognized
Cleveland Bay type of to-day, but much heavier boned and of
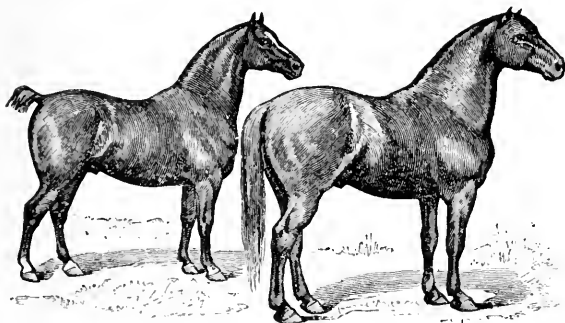
Fig. 30. Hackney Horse.   Fig. 31. Cleveland Bay Horse.

greater strength, have been bred almost pure for a very long
time back. The Cleveland Bay, as now defined by breeders, is
a carriage-horse, tall, and well-built, with considerable strength,
and very fine action. In color, he is usually of one of the
different shades of bay, with black feet, and a white star in the
forehead. The good action of the Cleveland Bay, together with
his strength and spirit and his gentle disposition, makes him not
only desirable as a carriage-horse, but also one very suitable for
all sorts of light work on the farm, and for drawing moderate
loads on the roads with considerable speed.

411. The Hackney.—The Hackney, like the Cleveland

Bay, has been only very recently recognized as a pure breed; but the progenitors of the Hackney have for a long time been bred almost pure in their native homes, Yorkshire and the Eastern Counties of England. The Hackney, like the Cleveland Bay, is a carriage-horse; that is, one remarkable for gracefulness of action rather than for speed or strength. He is not so tall as the Cleveland Bay, and in color may vary from black to gray, but dark-brown and bay are the colors most admired.

Draught Horses.

412. The Clydesdale.—The Clydesdale is so named from the dale or valley-land of the River Clyde in Scotland, the
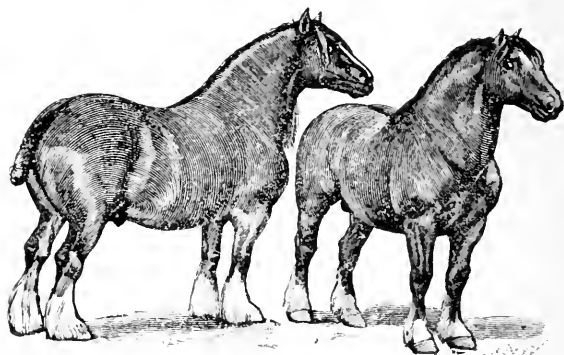
Fig. 32. Shire Horse.   Fig. 33. Clydesdale Horse.

district in which the breed originated, some time early in the last century. The Clydesdales are remarkable for their fine constitutions, high spirit, and great strength, so much so that they are not excelled by any breed in suitability for the drawing of heavy loads. They are of all colors; but bays, browns, and blacks predominate, although there are grays and chestnuts also. The favorite color of the Clydesdale, however, is bay, with a white "ratch" or stripe on the face, and with white on the legs below the knee. The presence of a heavy growth of long silky hair,

from the knee and hock to the fetlock, is regarded as a mark of quality and good blood. The Clydesdales have been of immense advantage to Canada in improving the common stock of the country. Clydesdale grades make good, useful farm horses, and, as a rule, bring prices which well repay the breeder. Pure-bred Clydesdales are imported into this country from Scotland in great numbers, and are also extensively bred here.

413. The Shire.—The Shire horse is descended from old English stocks, for the most part heavy horses bred for purposes of war in past centuries, and known by various names, as the Great Horse, the English Black Horse, and the English War Horse. The breed is very largely used in England for general farm purposes, and also (especially the larger specimens of them) as dray-horses in the great cities. In build, the Shire horse bears considerable resemblance to the Clydesdale, though he is often larger and stronger in the bone; and he is devoted to similar uses. Black; bay, and brown, are the favorite colors, the two latter being most in favor. Like the Clydesdale, the pure-bred Shire horse is heavily feathered below the knee and hock. Shire horses, both imported and home-bred, are now found in Canada quite numerously, and their number is rapidly increasing.

414. The Percheron.—The Percheron is named from the province *Perche* in northern France, in which district the breed is found in its greatest purity. It is sometimes called the *Norman*, and sometimes the *French Draught Horse*. It is probably descended from the ancient war-horse of Normandy, but possesses besides a large admixture of Arab blood. The Percheron horse is not quite so heavily built as the Shire or the Clyde; and he has greater activity of limb. He may be described as a horse uniting considerable strength with a fair degree of activity. In color, he is usually of a beautiful dappled gray; though he may be of other colors, and black is often preferred. The Percheron grade makes a useful farm horse, being especially suitable for drawing loads or doing comparatively heavy work at a rather quick pace.

415. The Suffolk Punch.—The Suffolk Punch is so named from the county of Suffolk in England, in which district

the breed has been raised for a very long time.   This breed of horses are remarkable for their strength of constitution, and their activity and endurance in all kinds of heavy farm work.   In general structure, they are perhaps shorter in the leg and deeper in the body than the other breeds of draught horses ; and though of lighter bone, are more compactly built.   Their color is uniformly chestnut.   Though not as yet very numerously introduced into Canada, they have many admirers, and will no doubt be one of our most useful breeds.
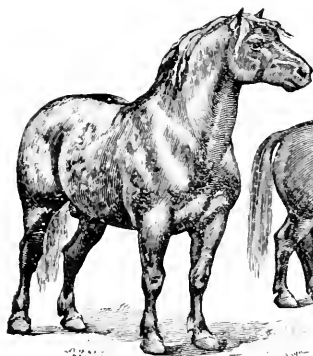
Fig. 34.   Percheron Horse.   Fig. 35.   Suffolk Punch Horse.
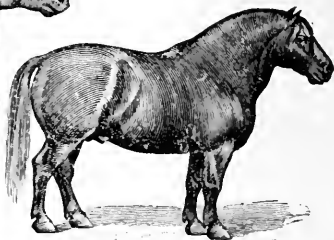
CATTLE.

416. Principal Breeds.—The breeds of cattle are usually classified as being either (1) beef-producing breeds, or (2) dairy breeds.   Some breeds, however, are useful for producing both beef and milk.

The principal *beef-producing breeds* that have been introduced into Canada are the Durham or Shorthorn, the Hereford, the Aberdeen-Angus Poll, the Galloway, the Devon, the Sussex, and the West Highland breed.   The principal *dairy breeds* are the Ayrshire, the Holstein-Friesian, the Jersey, the Guernsey, the Red Poll, and the Kerry and Dexter.

Of the breeds named above, it is claimed that the Shorthorn, the Devon, the Holstein-Friesian, and the Red Poll, are good for both beef-producing and dairy purposes.

Beef-Producing Cattle.

417. The Durham or Shorthorn.—This important breed of cattle is said to have had its origin in the blending made about 200 years ago of two sorts of large cattle formerly found in the valley of the Tees in England. But perhaps the real foundation of the breed ought to be set down as having been made in the
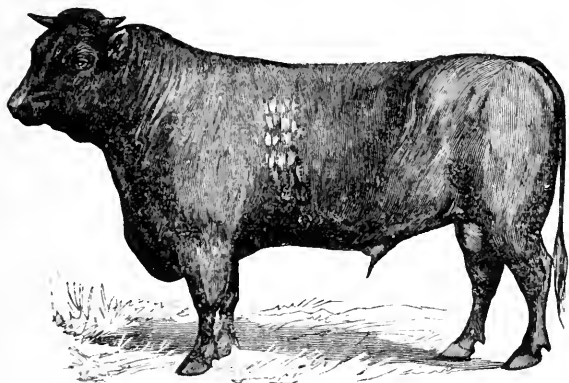
Fig. 36. Shorthorn Bull, *Baron Waterloo.* Owned by the Ontario Model Farm, Guelph, Ont.

last quarter of the eighteenth century at Ketton and Barmpton, in the county of Durham, by the Messrs. Charles and Robert Colling. These enterprising brothers, although quite young, had the sagacity to adopt the original methods of breeding which Robert Bakewell, the celebrated improver of Longhorn cattle and Leicester sheep (see section 437), had, for some time previous, been so successful in making use of; and their skill in applying his methods soon raised the Shorthorns to a pitch of excellence among British breeds of cattle which the breed has ever since retained. There are several famous strains of Shorthorns, each

known by the name of its founder, namely, the "Booth," the "Bates," and the "Cruickshank." The "Booths" derive their name from Thomas Booth, who lived at Killerby and Warlaby, in Durham, about the end of the eighteenth century, and from his two sons, John Booth, of Killerby, and Richard Booth, of Studley, in Yorkshire. The "Bates" families derive their name from Thomas Bates, of Kirklevington, in Yorkshire, whose improvements were begun about the beginning of the nineteenth century. The "Cruickshanks" derive their name from Amos and Anthony Cruickshank, of Sittyton, Aberdeenshire, who
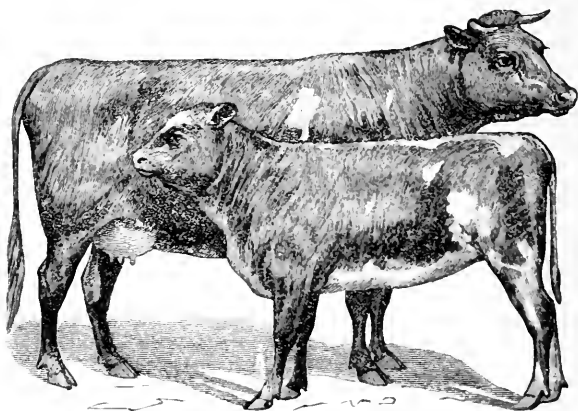
Fig. 37. Shorthorn Cow, *Matchless of Elmhurst 7th*; and Shorthorn Calf, *Matchless of Elmhurst 9th*. Owned by the Ontario Model Farm, Guelph, Ont.

began their work about 1838. Shorthorns make a good use of the food given them, "fattening as they grow," as the phrase is, and are not excelled for their early-maturing qualities. Probably, of all cattle, they attain to the heaviest weights. Moreover, when bred for the purpose, they prove very good milkers. They are also remarkable for the ease with which they adapt themselves to changes of climate or food. The standard color for a Shorthorn is red, or white, or roan; but red is

now the favorite color, and white is considered objectionable. Shorthorns have been more largely used for the improvement of other cattle than any other breed. In this way they have been of great service to Canada, and have been numerously imported for that purpose. They are also very extensively bred here.

418. The Hereford.—The Hereford breed of cattle had its origin in the county of Hereford, in England, and in the adjacent districts. This breed, and the Devon and Sussex breeds, are all supposed to be descended from the same stock, namely, an ancient native race, whole-red in color; but, in the case of the Hereford, there has been an admixture of the blood of a race of
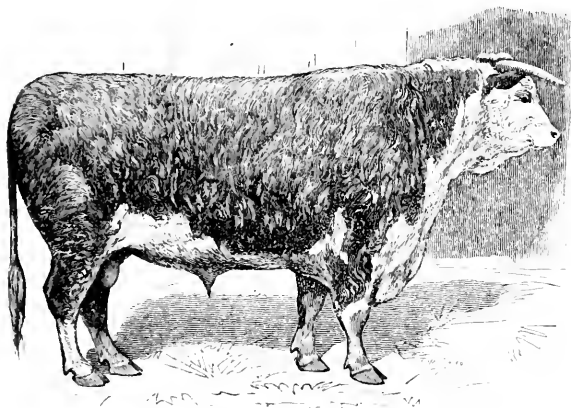
Fig. 38. Hereford Bull, *Conqueror*. Imported and owned by the
Ontario Model Farm, Guelph, Ont.

white cattle, formerly found in Wales. The third and fourth quarters of the eighteenth century were times of great energy and experiment among English breeders, and it is to the first of these periods especially that very many improvements in our live-stock are to be ascribed, although, as we have seen, the great improvements effected in the Shorthorns were made a little later. The improvement of the Herefords was principally effected by Benjamin Tomkins, who was born in Herefordshire

in 1745; and he is generally regarded as the founder of the breed, although much had been done before his time. The work of improvement begun by Tomkins and his predecessors was greatly extended by John Price, of Ryall, in Worcestershire, who was born in 1776. The efforts of the early improvers of the Hereford (as perhaps also was the case with the Devon and Sussex) were directed towards securing strength, endurance, and patience in their stock as draught cattle, quite as much as excellence in beef-production; though of course the disposition to mature
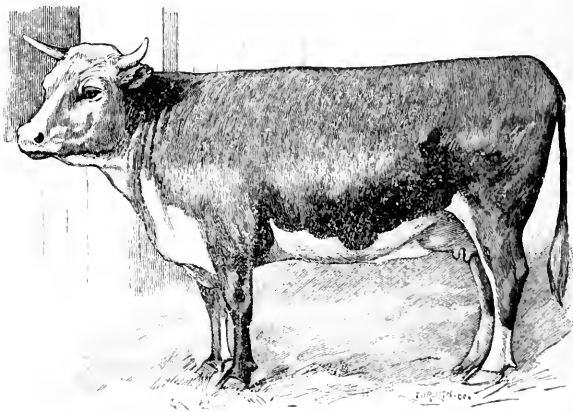
Fig. 39. Hereford Heifer, *Geranium.* Owned by the Ontario Model Farm, Guelph, Ont.

early, and to lay on beef of good quality, soon became recognized as the most important ends to be aimed at. The Herefords, as now bred, are noted for the uniformity of their markings, their docile dispositions, indicative of good fattening propensities, and for their high qualities as grazing cattle. They attain to good weights, mature early, and produce beef of very excellent quality. Moreover, their grades possess the same characteristics in a high degree. But their cows are not good milkers, so that they are little valued for dairy purposes. The color of the Hereford is

red and white in masses: the sides of the body being red; the face being always white; and more or less of white being on the belly, the breast, and the top-line, especially from the shoulders forward.

419. The Aberdeen-Angus Poll.—The Aberdeen-Angus and the Galloway breeds of cattle are supposed to be both descended from a wild race originally found in the districts of Scotland whence these breeds derive their names. The differ-
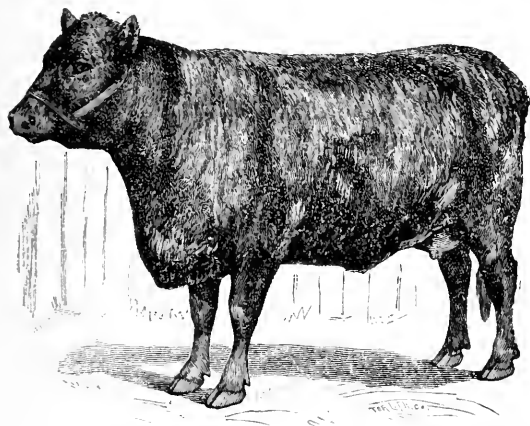
Fig. 40. Aberdeen-Angus Heifer. *Blooming Rose.* Owned by the Ontario Model Farm, Guelph, Ont.

ences now to be noticed between them are thought to be due to differences of climate, and other influences, as selection, treatment, and food, during the time that they have been domesticated. The systematic improvement of the Aberdeen-Angus was begun about the year 1808, by Hugh Watson, of Keillor, in Forfarshire; but it was greatly extended by William McCombie, of Tillyfour, in Aberdeenshire, who began his career as a breeder in 1829. This breed is remarkable for the excellent quality of its beef, and for the high percentage of meat in the carcass as compared with the weight of the living animal. Moreover, the

flesh is firm and finely grained, and well marbled and flecked
with fat, qualities which always ensure to it the highest market
price. The Aberdeen-Angus are "blocky" in build, the angles
at the hocks and quarters not being prominent. They are, as
their name implies, hornless; and, in color, they are completely
black. The grades of the breed resemble the pure-bred animals
in build and general appearance, and share with them, in a high
degree, their excellent beef-producing qualities.

420. The Galloway.—The Galloway breed of cattle is one
of the most ancient of British breeds. The district in Scotland
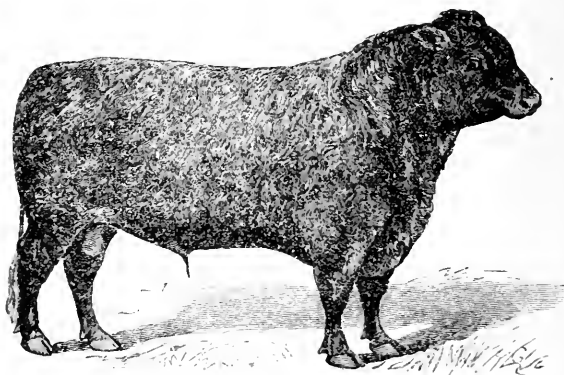
Fig. 41.   Galloway Bull, *Borderer*.   Imported and owned by the
Ontario Model Farm, Guelph, Ont.

whence they derive their name is a wet country of mountain and
moorland, heather and whin; and the Galloways, having been
bred there from time immemorial, have developed hardy consti-
tutions, and thus are able to endure the cold and wet winters of
the country, though staying out in the field, or sheltered under
open sheds merely. They are endowed with long shaggy coats
of hair, having a thick mossy undercoating; and thus, with their
hardy constitutions, sturdy dispositions, and excellent feeding
habits, they are admirably fitted for use on our western ranches.
Moreover, their meat is of the highest excellence, being firm,

juicy, and tender, and free from masses of fat. In general external appearance, the Galloways resemble the Aberdeen-Angus, being hornless, and completely black in color; but they are somewhat smaller in size than the Aberdeen-Angus, and somewhat coarser in bone, while their coating of hair is much heavier.

421. The Devon.—The Devons are one of the most ancient and pure of the British breeds of cattle. They derive their name from the county of Devon, in England, in which district they are found most numerously, and in the purest form. The Devons are distinguished for their pleasing appearance, being of
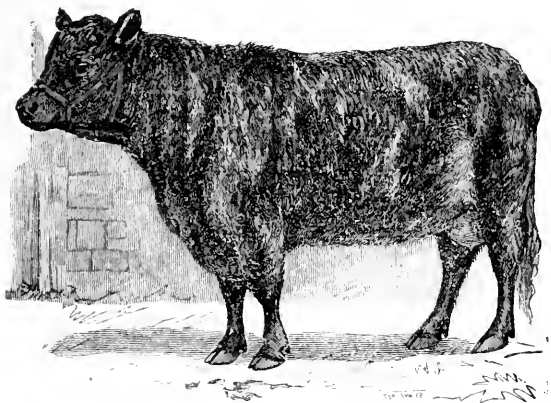
Fig. 42. Galloway Cow, *Gem 2nd of Drumlanrig.* Owned by the Ontario Model Farm, Guelph, Ont.

a bright red color and elegant form, and have thus won for themselves their popular name, the "English Rubies." More-over, being of a very gentle disposition and hardy constitution, and withal easy to keep, the Devon has long been a favorite as a family cow. The Devons are profitable as meat-producers, if the quantity and quality of the food they consume is to be taken into consideration, since their meat is of the finest texture and flavor, and they are able to make use of but scant pasturage as

fare.   But they do not attain to the heavy weights of some of the larger breeds, nor do they seem to be as suitable for stall fattening as these.   The Devons, moreover, have acquired a good reputation as a dairy breed, as their milk ranks high for its butter-making quality, and is fair in quantity.   Formerly, when oxen were more used for working purposes than they are now-a-days, the Devons were valued for yoke-cattle, perhaps more highly than any other breed.
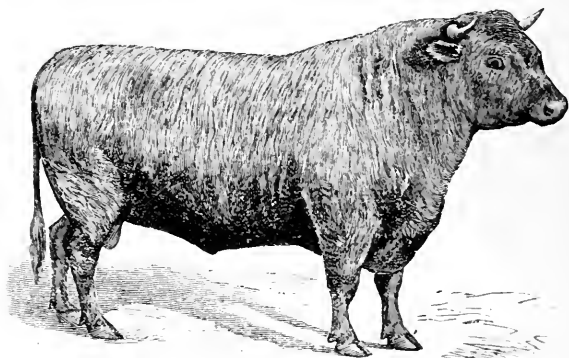
Fig. 43.   Devon Bull, *Rose's Duke*.   Imported and owned by the Ontario Model Farm, Guelph, Ont.

422. The Sussex.—The Sussex cattle are dark-red in color, and in this respect, as well as some others, resemble the Devons; but they have larger heads and frames, and their horns are longer, wider, and more upturned.   Moreover, they are deeper bodied, stronger in the bone, and attain to heavier weights. They are good grazers, take on flesh easily, and are very hardy, though they are somewhat slower in maturing than some other breeds.   Their ability for milk-production is not of a high order.

423. The West Highland Cattle.—The West Highland cattle, or Kyloes, are found in all the Highlands of Scotland, but in greatest perfection in the larger Western Islands.   Bred from time immemorial in the cold, humid climate and on the

coarse pastures of the bleak hills and glens of their native country, they have developed great hardiness of constitution and the ability to thrive and fatten on meagre fare, such as some of the other breeds we have mentioned would starve upon. In symmetry of form, nobleness of bearing, and picturesque beauty, they are unequalled by any other breed, and they are so highly prized for their appearance that they are often kept instead of deer in the parks of noblemen. In color, they are generally
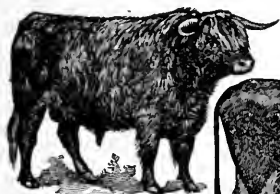
Fig. 44. West Highland Bull.   Fig. 45. Sussex Cow.
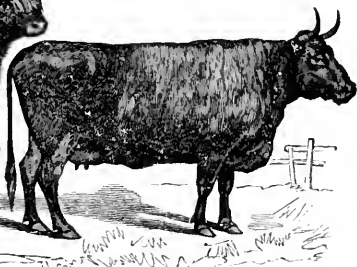
black, but sometimes they are of a tawny yellow, or light dun, and these are the colors that are preferred. Their hair is thick and shaggy, and their horns are long and set wide apart. Their meat is of excellent quality. Owing to their capability of enduring all sorts of weather with little or no artificial protection, and also to their staying powers as travellers, and their ability to turn coarse and meagre fodder into the best quality of meat, they are becoming favorites with the ranchmen of our Northwest and the far Western States. They are not, however, good milkers, and mature rather slowly. They are also somewhat small in size.

The Dairy Breeds.

424. The Ayrshire.—The Ayrshire cattle derive their name from Ayrshire in Scotland, the centre of the district in which the breed originated. The early history of the Ayrshires
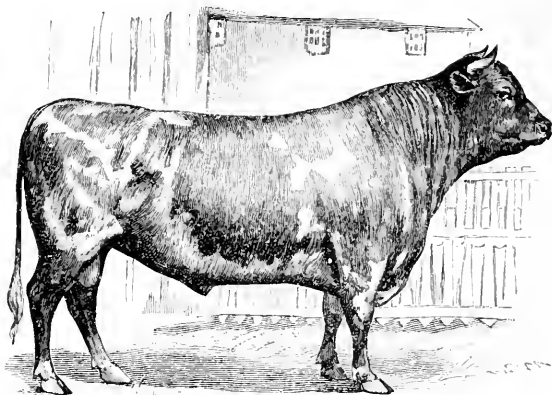
Fig. 46. Ayrshire Bull, *Campbell of Drumlanrig.* Imported and owned by the Ontario Model Farm, Guelph, Ont.

is obscure, but it is thought that they are the result of improvements made at intervals during the seventeenth and eighteenth centuries by means of crossings of the native stocks of the district with West Highlanders, Dutch cattle, Shorthorns, Alderneys (see section 427), and Kerries. The Ayrshires are hardy,
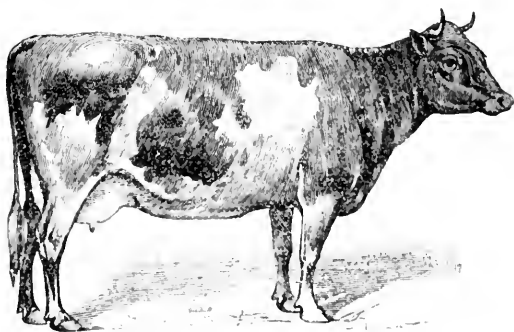
Fig. 47. Ayrshire Cow, *Nelly May, 2nd.* Owned by the Ontario Model Farm, Guelph, Ont.

and possess the capability, rare in dairy cattle, of making the best use of pastures that are both sparse and poor. They are almost uniformly good milkers, and are distinguished for the large returns they give in proportion to the amount of food they consume. Their milk is good for both butter and cheese, but especially so for the latter. Their calves are easily prepared for veal. In size, the Ayrshires are not large. In color, they are generally brown and white; that is, brown spotted or flecked with white; the color, on the whole, inclining to brown.
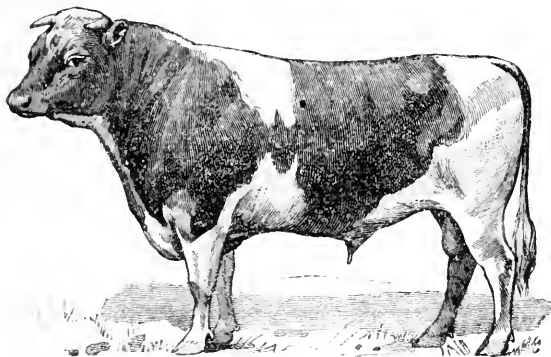
Fig. 48. Holstein-Friesian Bull, *African Prince*. Owned by the Ontario Model Farm, Guelph, Ont.

Oftentimes red is found in place of brown. Their horns are of medium size, and point upwards rather than inwards at the tips. It should be said, also, that the Ayrshires are a most valuable breed for the improvement of the common stock of the country for all dairy purposes. Moreover, their cows, when finished as milkers, lay on flesh easily, and produce excellent beef.

425. The Holstein-Friesian.—The Holstein-Friesian breed comes from Holland. It is rapidly growing in favor as a dairy breed, both in the United States and Canada. In size, Holstein-Friesians are nearly equal to Shorthorns, but they lack the fulness and evenness of form possessed by the latter. They are considered quite hardy and vigorous, and their early-maturing

tendencies are well-developed.   Their milk-yield is usually large, sometimes very large, and the quality of their milk for the production of both butter and cheese is good—being especially so for cheese.   Their milk is also excellent for the rearing of calves, being rich in casein, and the calves may be made to attain heavy weights at a comparatively early age.   In color, the Holstein-Friesians are invariably black and white.   These colors are always "whole"; that is, they are never intermixed.

426. The Jersey.—The cattle of the island of Jersey have been bred pure for centuries, the laws of the island strictly preventing the importation of animals of any other breed.

Fig. 49. Holstein-Friesian Cow, *Verasina.* Owned by the Ontario Model Farm, Guelph, Ont.

Hence the Jersey cattle constitute one of the purest and most clearly-defined breeds in the world.   Jerseys are remarkable for their butter-producing qualities, both as regards the quantity of the butter-yield as compared with the milk-yield, and for the quantity of the butter-yield as a whole.   Moreover, Jersey butter is of the highest excellence, being of fine color and delicate flavor.   Their milk, however, is not well adapted for the making of cheese.   Jerseys are small in size, and rather slender in frame : and as they are endowed with a fine, deer-like form, with much docility of disposition, they are often made pets of by those who
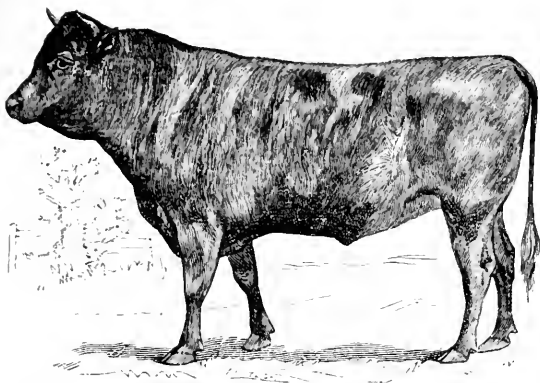
Fig. 50. Jersey Bull, *Pogis of Flamboro.* Owned by the Ontario
Model Farm, Guelph, Ont.

keep them. In color, they are gray-fawn and white, yellow-
fawn and white, gray-dun and white, or a cream-colored fawn;
but solid colors are always preferred. Their horns are small,
curved, usually black in color, and are well set over the forehead.
The grades of the Jersey possess, in considerable degree, the
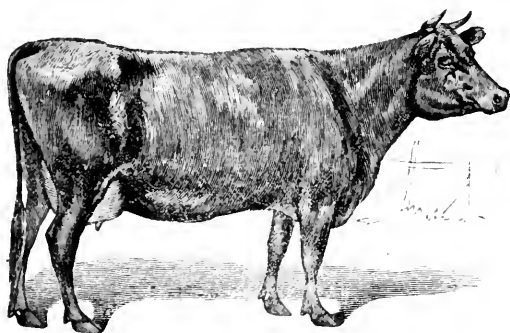
Fig. 51. Jersey Cow, *Lisgar's Rose.* Owned by the Ontario
Model Farm, Guelph, Ont.

excellent butter-producing qualities of the original breed.   The milk of Jerseys is too rich in butter-fat for calf-raising, so that the calves of the breed are generally raised by hand upon the skimmed milk.

427. The Guernsey.—The cattle of the island of Guernsey, like those of the adjacent island of Jersey, have been bred pure from time immemorial, so that they also constitute one of the purest breeds in the world.   The same may be said of the cattle of Alderney, another of the Channel Islands.   Compared with the Jerseys, the Guernseys may be said to resemble them considerably, both in appearance and in the qualities of a dairy
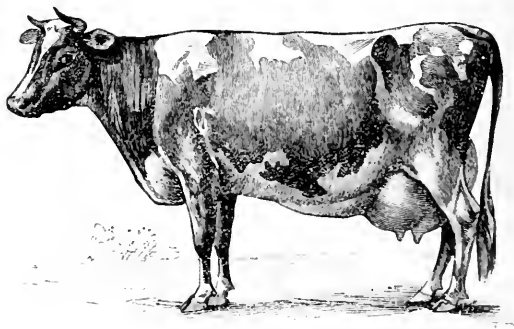
Fig. 52. Guernsey Cow.

animal.   But they are somewhat larger than the Jerseys, and a little heavier in the frame; and they are more fleshy, and more easily fattened and turned into beef, when this is necessary. Their butter, like the Jersey butter, is rich in color and fine in flavor; but their milk, like the Jersey milk, is not well suited either to cheese-making or calf-raising.   However, for the family dairy, perhaps no better animal is obtainable than the Guernsey cow.   In color, the Guernsey varies from a light red to an orange or lemon fawn, with, however, a considerable admixture of solid white, in most instances.

428. The Red Poll.—The original home of the Red Poll is in the counties of Norfolk and Suffolk, in England, where the

native cattle at one time seem to have received an infusion of
Galloway blood.   Red Polled cattle are hardy, and lay on flesh
easily on pastures that are but moderately good; but they are only
of medium size, and they do not mature as early as some other
breeds.   Their milking qualities, however, are of a high order,
though they are more distinguished for the length of the period
during which they give milk than for their fulness of flow at any
one time.   At the same time, they are a good beef-producing
breed.   On the whole, the Red Poll constitutes what is called a
good "general purpose cow."   In color, it is of a deep rich red,
and it is distinguished by a tuft or crest of hair, which rises from
the upper part of its forehead.   In disposition it is gentle.
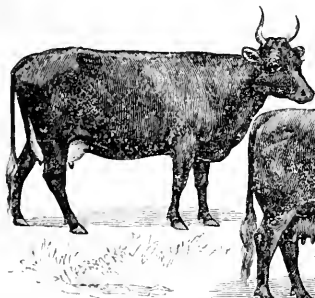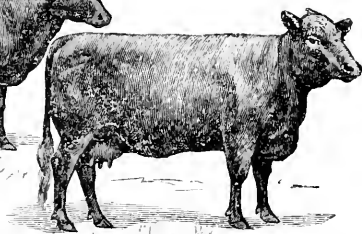
Fig. 53.   Kerry Cow.   Fig. 54.   Red Poll Cow.

429. The Kerry and the Dexter.—The Kerry breed of
cattle are small, finely-shaped animals, generally black in color,
and hence popularly called "blackskins," though sometimes red
or brown.   The udders, however, should always be white.   Their
horns are small and upturned.   They come from the county of
Kerry, in Ireland.   The Kerries produce most excellent milk, and
in this respect are thought by some to be equal to the Jersey.   Their
flesh is of fine quality.   Moreover, they probably excel all other
dairy cattle in hardiness of constitution and in ability to thrive on
sparse pastures.   In general appearance the Kerry cattle are so
attractive that they are often kept by noblemen and others in

parks, instead of deer. The Dexter cattle are a cross between the Kerries and an unknown breed. They resemble the Kerries in general appearance and in qualities, but are somewhat larger.

<center>SHEEP.</center>

430. Principal Breeds.—The principal breeds of sheep that have been imported into Canada are the following:

(1) The Merino, classified as *fine-woolled* sheep.

(2) The Southdown, the Dorset, the Shropshire Down, the Hampshire Down, the Oxford Down, and the Cheviot, classified as *medium-woolled* sheep. In this list, the wools of the respective breeds decrease in fineness as we go down the list. But a part of the wool of the Cheviot is finer than that of the Dorset, although another part is coarser than that of the Oxford Down.

(3) The Leicester, the Lincoln, the Cotswold, and the black-faced Highland sheep, classified as *coarse-woolled* sheep. In this list, also, the wools of the respective breeds decrease in fineness as we go down the list.

Another mode of classification is that of *long-woolled* sheep, *middle-woolled* sheep, and *short-woolled* sheep. It is very difficult, however, to say positively in which of these two classes some of the breeds mentioned should be placed. But it may be said, that, roughly speaking, the shorter the wool is, the finer it is, though there are exceptions to this rule. The Southdown, the Dorset, the Shropshire Down, the Hampshire Down, and the Oxford Down, are generally spoken of as middle-woolled sheep, though sometimes the Southdown is called a short-woolled sheep; but, strictly speaking, the Merino is the only short-woolled sheep among all those mentioned in our list. The Leicester, the Lincoln, and the Cotswold, are always spoken of as long-woolled sheep. Again, the Southdown, the Dorset, the Shropshire Down, the Hampshire Down, and the Oxford Down, are all spoken of as "Down" sheep; but, strictly speaking, neither the Dorset nor the Shropshire Down are of the original Down breed.

Sheep are generally reared for the purpose of producing both wool and mutton. Some breeds are most suitable for producing

wool, others for producing mutton; others, again, seem equally
suitable for the production of both wool and mutton. No one
breed, however, unites in itself the highest excellences in respect
to the production of both these products.

Fine-Woolled Sheep.

431. The Merino.—The Merino is the chief of the fine-
wool breeds. It now embraces many distinct strains, both in
Spain, usually looked upon as its original home, and in Germany,
France, Australia, the United States, and Canada. It has, how-
ever, been but sparingly introduced into Great Britain. The
Merino breed has shown a remarkable power of adapting itself to
variations of climate, and thus it has been largely instrumental
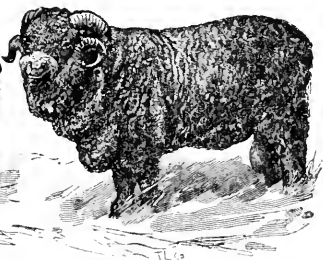
Fig. 55. Merino Ewe.   Fig. 56. Merino Ram.

in effecting improvements in other breeds; but in order that it
may retain the extreme fineness of its wool, considerable dryness
in the climate seems to be required. The chief excellences of the
wool of the Merino, in addition to its remarkable fineness, are the
weight and closeness of its fleece, the high degree of its "felting
quality,"* and the luxuriance of its "yolk."† Indeed, in felting

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* By "felting" is meant the tendency which wool fibres possess, as
distinguished from many other textile fibres, of clutching and holding fast
one another. As a rule, the shorter and finer the wool is, the greater is its
felting quality, and the longer and coarser it is, the less is its felting quality.

† By "yolk" is meant the soapy secretion of potash salts and oil found in
the fleeces of all sheep. It serves as a protection to the fleece, rendering it
impervious to moisture, and preserving it more or less soft, pliant, and silky.
It is almost entirely soluble in water, and can be easily washed out.

quality, and in abundance of yolk, the Merino excels all other breeds of sheep mentioned. The Merino possesses a good appetite, and a quiet, patient, and tractable disposition. The flesh-producing properties of the breed, formerly not good, have been much improved of late by careful breeding. In external appearance, the Merinos are remarkable for their well-curved horns, set widely apart; the completeness of their fleece over head, legs, and feet; and for the deep folds of their skin on their necks, shoulders, and rumps; but this wrinkling, or folding of the skin, once thought necessary to the fineness of the wool, is not now quite so highly valued.

Medium-Woolled Sheep.

432. The Southdown.—The modern improved Southdown is descended from an ancient breed of sheep that fed upon the
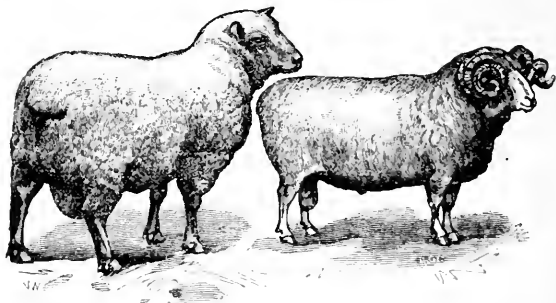
Fig. 57. Southdown Ram. Fig. 58. Dorset Horned Ram.
The Southdown Ram is *Duke of Cambridge.* The Dorset Horned Ram is
Monarch. The former has been imported. They are both owned
by the Ontario Model Farm, Guelph, Ont.

high-lying lands, or "downs," of southern England. The improvement of the breed is largely due to John Ellman, of Glynde, in Sussex, whose name is one of the most memorable in the history of stock-breeding. Much credit, too, is due to his son and successor, now known as the younger Ellman, and also to the late Jonas Webb, of Cambridgeshire. The Southdown is distinguished by its broad and compact body, its arched neck,

the dusty-brown color of its legs and face, its wide, deep, and forward-projecting breast, and its square and thick buttocks. Its fleece is finer than that of any other native British breed. Its mutton, too, is of the choicest quality, being close-grained, well-flavored, juicy, and tender. The compactness of its wool enables it to brave both cold and wet, and it is able to keep in good condition on pastures that are scant. Its habits are active, and yet docile. As a breed, the Southdowns are prolific, and early to mature; and their lambs are hardy and easily raised. On the whole, the Southdown, while somewhat smaller in size, is a finer and more highly-bred animal than any of the other Down breeds of sheep, and in consequence has been much used, especially in earlier times, in imparting to them, by crossing, some of its own characteristic fineness, both of wool and mutton.

433. The Dorset.—The Dorset, sometimes called the Dorset Horned Sheep, has been bred for time immemorial in Dorsetshire, Hampshire, and adjacent districts, in England. Its modern improvement is due entirely to careful selection. The Dorsets are a white-faced, white-legged breed, and both sexes have horns. Their foreheads are always adorned by a small lock of close wool. They are hardy of constitution, and quiet and docile in disposition. But what most distinguishes them from other breeds is their remarkable fecundity. Their ewes are good nurses, and frequently rear lambs twice in the same year. Therefore, since they fatten early and easily, and lay on meat of excellent quality, they ought to play an important part in the sheep-husbandry of Canada in supplying lambs for the spring and Christmas markets. The fleece of the Dorset is of good weight, and ranks next to the Southdown in fineness. Their wool, like that of the Southdown, is comparatively short.

434. The Shropshire Down.—The Shropshire Down is descended from sheep that used anciently to be bred on the open commons of Shropshire, but it has been greatly improved: first, by crossing with Leicesters, Cotswolds, and Southdowns, especially the Southdowns; and, secondly, by careful selection, continued now for many years. As compared with the Southdowns, the Shropshire Downs are considerably heavier, both in body and

in fleece, and are quite as robust. Like the Southdowns, their face and feet are of brown color, but darker; and the head of the Shropshire should be well-covered with a close-fitting cap of wool: the legs also should be wool-covered. Its neck should be of medium length and muscular, and its girth behind the shoulders should be very great. The Shropshire Down has been very extensively imported into Canada, and has proved itself well-suited to the climate and other requirements of the country, and has consequently been much used in the improvement of our common home-bred sheep, with which it forms excellent crosses. Its fleece, which is of medium fineness, is of more than average weight, and the quality of its mutton is
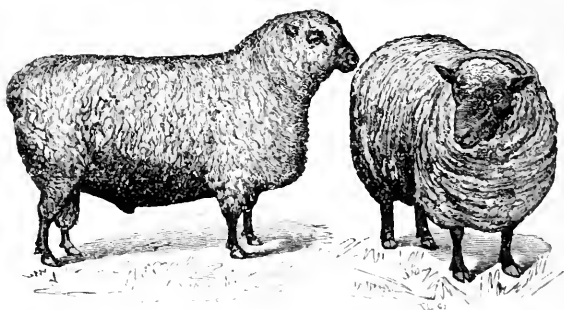
Fig. 59. Shropshire Down Ram.   Fig. 60. Hampshire Down Ram.
The Shropshire Ram is *il rangler*. It was imported, and is owned by the
Ontario Model Farm, Guelph, Ont.

excellent. In general appearance, the Shropshire Down and the Oxford Down resemble one another, but the ear of the Shropshire is shorter and rounder, the wool on its head is closer, and its fleece in general is finer; while the wool on the forehead of the Oxford Down is something like a top-knot, and its fleece is often gathered into flakes or locks. In England, Shropshire Downs are now known simply as "Shropshires," because they are, in strictness, not a Down breed, although they have been improved by admixture with the Downs.

435. The Hampshire Down.—The Hampshire Down

originated with a blending of the old horned white-faced native breeds of Hampshire, Wiltshire, and Berkshire, in England, with the improved Southdown breed. This was accomplished principally by the late William Humphrey, of Oak Ash, in Berkshire, who first crossed his native Hampshire ewes with Southdown rams in 1842. Much improvement, too, was effected by his neighbor, James Rawlence, of Bulbridge. There had, moreover, been previously a crossing with the Cotswold. Hence the Hampshire combines the fine mutton-producing and wool-producing qualities of the Southdown, with the superior size and stronger constitution of the original stock and the Cotswolds. Indeed, the Hampshire Down sheep is the heaviest of all the Down breeds, and, of all other breeds, it is, as a rule, excelled in weight only by the Lincolns. The Hampshire Down is remarkable for its early-maturing qualities, in which, it is claimed, it is superior to other breeds. Moreover, it fattens well, and its mutton has a good proportion of lean meat. In respect to appearance, the Hampshire Down has a large head, with a Roman nose; its body is long; and its face, feet, and shanks, are, in color, of a rich dark brown. Its head should be well-covered with wool, both between the ears and over the cheeks. Its ears should be long, thin, and inclined to fall slightly outward. Its neck is thick, muscular, and somewhat erect.

436. The Oxford Down.—The Oxford Down is comparatively a recent breed, and is the result of a blending of the Hampshire Down with the Cotswold, effected principally by Samuel Druce, of Eynsham, Oxfordshire, who began his work about 1833. Their native home is the wet, springy lands of Oxfordshire and Gloucestershire, in England, along the foot of the Cotswold Hills. The hardiness of the Oxford Downs makes them well adapted to localities favored with only inferior herbage. And as they attain to heavy weights at a reasonably early age, and produce a large weight of wool, they are a very valuable breed. The face of the Oxford Down is generally brown, and though sometimes gray, it ought not to be speckled; and the legs are of dark brown or smoky color. As distinguished from the Shropshire Down, the head of the Oxford Down is longer, the

nose thinner and more Roman-shaped, and the fleece looser and more lustrous. The wool of the Oxford Down is comparatively long, and principally used in making worsted yarns and cloths.

437. The Cheviot.—The Cheviot sheep is named from the Cheviot Hills of southern Scotland, but it is found numerously throughout all the hilly districts of the Scottish Lowlands. Its origin is obscure. It is, undoubtedly, an ancient breed, improved in size by means of a cross with the Lincoln. The Cheviot resembles the Southdown in qualities, but it is much better able to endure cold weather. Some of its wool is of a high degree of fineness and felting quality. The Cheviot is an early-maturing animal, and its mutton is of good quality. In respect to external appear-
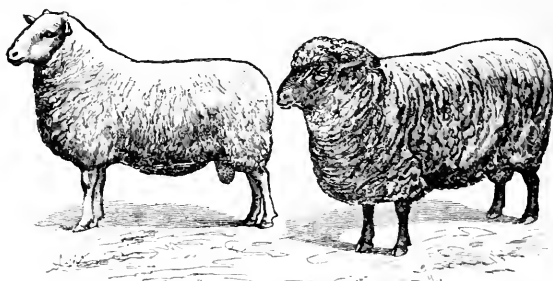
Fig. 61. Cheviot Ram.   Fig. 62. Oxford Down Ram.
The Oxford Down Ram is *Duke of Gloucester*. It was imported, and is owned by the Ontario Model Farm, Guelph, Ont.

ance, the head of the Cheviot is Roman-nosed, bold, and free from wool; its ears are erect, somewhat long, and covered with fine, hard, white hair; its face and feet are white; its body is long; its wool is short, fine, and free from "kemp" hair; and both sexes are hornless. There is no breed of sheep so well adapted to elevated pastures that have herbage of only moderate quality; and in the hilly and exposed parts of our country, the Cheviot ought to be a favorite breed.

Coarse-Woolled Sheep.

438. The Leicester.—The Leicesters are so named from

Leicestershire, in England, where they were first established as an improved breed. This was accomplished by Robert Bakewell, of Dishley Hall, in that county, to whose genius and practical skill as a breeder the stock-raising industry of the world owes more than to any other man. His work of improvement began about the year 1755, and he soon attained results that have since been scarcely excelled.* The Leicesters are now perhaps the most widely diffused of all the pure-breeds of sheep. And they no doubt have been used more than any other in the improvement of other breeds, and in the establishing of new breeds. The principal characteristics of the Leicesters are their decided aptitude to fatten easily and mature early, and their extreme docility. In form they are very attractive, possessing a full, compact body, broad, flat, and straight above, and straight below, with a comparatively small head, and with rather small bones. Their face is white in color, and wedge-shaped; their forehead is bare; their ears are long, thin, and mobile; their neck is rather short, and set nearly on a level with the back; their breast is deep, wide, and prominent; their legs and feet are white; and both sexes are hornless. The wool of the Leicesters is long, soft, sometimes a little curly, and of good weight. Their flesh is of good quality, especially when young; and they yield a fair return of it in proportion to the amount of food they consume. But they are considered not quite so hardy as some of the other breeds, nor do they increase quite so rapidly. The great value of the breed lies in the excellent results which are produced when it is judiciously used for crossing purposes.

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*ROBERT BAKEWELL (born, 1726; died, 1795) is the most memorable name in the annals of agriculture. His genius as a stock-breeder has never been equalled. Before his time, breeding had been a mere hap-hazard practice of the individual stockman; it is scarcely too much to say that after his time it soon became recognized, largely through his influence, as both a science and an art. Besides his remarkable improvements in Leicester sheep, Bakewell was equally successful with Longhorn cattle and heavy cart-horses—the latter now known as "Shires." The Longhorn breed of cattle, however, though still existing, and by some breeders most highly thought of, has never become generally popular. Unfortunately, Bakewell was a man of secretive disposition, and much of his knowledge died with him.

439. The Lincoln.—The Lincolns were originally large and ungainly sheep that were bred from time immemorial on the wolds and heaths of Lincolnshire, in England; but, by crossing with the improved Leicester, they have become greatly changed, and are now ranked as one of the most useful breeds. In frame, they are larger than the Leicesters (they are, indeed, the heaviest of all our breeds), and, if possible, shorter in the neck; their fleece is heavier, and their wool longer. Their wool is, in fact, the longest of all British breeds, being sometimes over 20 inches in length. It is usually massed in flakes or strands, and thus
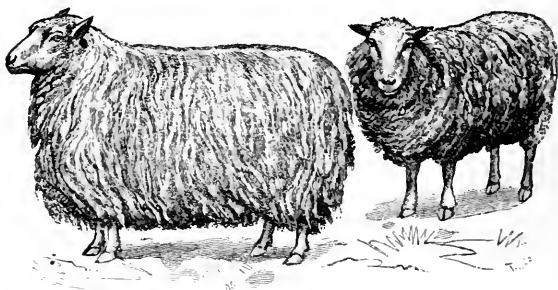
Fig. 63.   Lincoln Ram.   Fig. 64.   Leicester Ewe.
The Leicester Ewe is *Lady Polworth*, and is owned by the Ontario Model
Farm, Guelph, Ont.

gives to the breed a characteristic appearance. Moreover, it is further distinguished by a peculiar brightness, or *lustre*, which adds much to its value. With good management, the Lincoln sheep thrive well, especially when raised on soils that supply an abundance of succulent herbage. For the production of mutton, however, the Lincoln is inferior to the Down breeds, and also to the Leicester.

440. The Cotswold.—The Cotswolds were originally a heavy-bodied, long-woolled breed of sheep that were bred since time unknown on the Cotswold Hills in England, principally in Gloucestershire. A crossing with the Leicester somewhat reduced the size and fleece-weight of the original Cotswolds; but it also

made them more comely, gave them an aptitude for maturing
earlier, and otherwise improved them.   So that the Cotswolds
of to-day are much prized as a hardy, docile, rapid-growing, and
easy-fattening breed, and one able to make the best use of
herbage of varied quality, and to attain to comparatively great
weights.   Their fleece is heavy, and their wool is long and of
excellent combing quality.   Their mutton, however, like tha of
most of the long-woolled sheep, is somewhat inferior to that of
the Down breeds.   In color, the face and legs of the Cotswold
are sometimes white, but the white is very frequently marked by
dashes of brown or gray.   The Cotswolds are distinguished by a
heavy tuft of wool which hangs over their forehead.   As com-
pared with the Leicesters or Lincolns, their necks are more erect,
and they carry their heads more nobly.

Fig. 65.   Blackfaced Highland Ram.   Fig. 66.   Cotswold Ram.
The Cotswold Ram is *Mentor*, and is owned by the Ontario Model Farm,
Guelph, Ont.

441. The Black-Faced Highland Sheep.—The Black-
faced or Heath breed of sheep is found largely in all the High-
lands of Scotland, and also in all the hilly parts of the Lowlands
of Scotland and the mountainous districts of northern England.
It is one of the oldest breeds of Britain, its origin being lost in
obscurity.   The Black-faced sheep are small in size; but they
are remarkable for their activity and hardiness, and they can live
on the coarsest and scantiest herbage.   In Scotland, they can

subsist for a time on heather. Both males and females have horns, although sometimes the horns are wanting in the females. The horns of the males are large, long, and spirally twisted; but in both sexes they should be set low, and turned backwards rather than forwards. Their face and legs are black, or black and white—not brown, or of russet color, as in the Down breeds. Their mutton is of a peculiarly fine flavor, and always commands the highest market price. Their lambs fatten easily. Their wool, however, is open, coarse, and inclined to be hairy; but it is very suitable for the manufacture of coarse cloths, rugs, and carpets, and is much used for these purposes. These Black-faced sheep may yet prove a most valuable breed in the mountainous districts of the Dominion, both in the east and in the west.

SWINE.

442. How the Modern Breeds of Swine Originated.

It is generally admitted that the many different kinds of domesticated swine have all had their origin in wild species similar to those found in some parts of the world to-day. In Britain, however, the hog has been domesticated for a long time, and the many kinds of swine that are now found there seem to be descended from two very distinct stocks; namely (1) *the old English hog*, a large animal, found principally in the northern and western counties of England, tall, gaunt, very long in the body, with pendent ears, and a thick covering of bristles; and (2) *an ancient Scottish breed*, small, dusty-brown in color, with upright ears, and coarse bristles along the spine, found principally in the mountainous parts of Scotland. From these very distinct breeds have been obtained, by selection, crossing, and the admixture of other breeds, the many varieties of the modern British pig; but in their improvement two foreign breeds have been of especial service: (1) *the Chinese or Siamese pig*, varying in color from a pure white to a pure black, and remarkable for its early-maturing propensity and its fineness of bone; and (2) *the Neapolitan pig* of Italy, an almost hairless breed, having a slaty-blue colored skin, and remarkable for its extreme fineness of bone. It is to the Chinese breed, however, that most of the improvement mentioned above is to be ascribed.

443. Desirable Characteristics in Swine.—In all breeds of swine the following characteristics are desirable:

(1) Ability to make a good use of a large amount of food.

(2) Quietness of disposition, without which, indeed, the above characteristic cannot be manifested.

(3) An aptitude to mature early.

(4) The production, when slaughtered, of a small amount of offal, or waste, in proportion to the original live weight.

These characteristics belong, in a greater or less degree, to all domesticated swine, but in a modern improved breed they are required to be specially developed.

444. Principal Breeds.—The different breeds of swine are sometimes divided into two classes, in respect to size; namely, *the small breeds*, and *the large breeds*. Authorities differ, however, as to which of these classes certain breeds belong to. Among the small breeds are generally ranked the Small Yorkshire, the Suffolk; the Essex, and the Improved Berkshire. Among the large breeds are generally ranked the Middle Yorkshire, the Large Yorkshire, the Tamworth, the Duroc or Jersey Red, the Chester White, and the Poland China. The Suffolk, Essex, Berkshire, Yorkshire, and Tamworth, are English breeds; the Duroc or Jersey Red, the Chester White, and the Poland China, are American breeds. All these breeds have been introduced into Canada, and several of them are extensively bred here.

Note.—There is not the same definiteness in the classification of the breeds of swine that obtains in other kinds of live-stock. This is largely owing to the want of sufficient association among the breeders of the different classes. In England, the Berkshires and the Tamworths are always separately classified; but the other breeds are generally ranked either as "blacks," or as "small whites," "middle whites," or "large whites." In the United States, the classification is more distinct; but the American names and English names do not always correspond.

With respect to the Essex, it should be said that, though mentioned here, since its name often appears in lists of swine, yet it is considered extinct in England, having been absorbed by too much crossing with the Berkshire and Suffolk It was a wholly black breed, somewhat small in size, and was developed by Fisher Hobbs, of Essexshire, about the year 1840, out of the Neapolitan breed. The modern Suffolk, which greatly resembles it, and to some extent owes its origin to it, may be said to have taken its place. In the United States there is also a breed named the Essex. It is black in color, and is supposed to owe its origin to the original English Essex breed.

The Small Breeds.

445. The Small Yorkshire.—The small Yorkshire is somewhat similar to the other types of Yorkshire pigs described in section 448, differing from them, however, very considerably in size and fineness of build. It is, indeed, the smallest and finest of all the white breeds of swine. In external appearance, it is distinguished for its short dished face or snout; its short, thick jowl; its long, heavy, deep body; its short legs; and its remarkably fine bone. No breed matures earlier, fattens more quickly, or is more docile, than the Small Yorkshires, and in Britain, where they have long been bred, they are very popular.
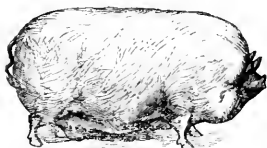
Fig. 67.   Small Yorkshire Sow.   Fig. 68.   English Suffolk Boar.
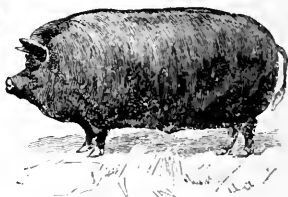
446. The Suffolk.—The improved Suffolk breed of pigs, as recognized and bred in England, is a race of small, hardy animals, altogether black in color, with little short heads, great jowls, broad foreheads, dished faces, and short broad ears, inclining to droop forward. Their bodies are cylindrical, and comparatively long; their hams, well developed; their legs, short, and small in the bone; and their hair, long, fine, and silky. They are not large eaters, and thrive well on fare not of the best. Moreover, they mature early. They are sometimes thought to fatten too easily, but this fault is no doubt due to injudicious feeding. When properly fed, they produce a large proportion of lean meat. They are hardy, and stand both heat and cold well. In Britain

they are a popular breed, and are especially valued as consumers of the waste products of the dairy or market garden.

The Suffolk, as bred in the United States, and also to some extent in Canada, is quite distinct from the Suffolk, properly so-called, described above, being in origin merely a variety of the English white Yorkshire, and corresponding in size to the Middle Yorkshire, described in section 448. This American Suffolk, as it may be named, is entirely white in color, and is characterized by a small and very short head; a dished face; short, thin, upright ears; a short neck; good length of body; well filled-out flanks; fine bone; pinkish skin; and fine, silky hair. It is much prized for the delicacy of its flesh, and for its early-fattening qualities, and is popular in some parts of the United States, and also in Canada.

447. The Berkshire.—The Berkshire is probably the most numerous of all the British breeds of swine. It has been extensively imported into Canada, and has been very greatly instrumental in improving our common stocks of swine, perhaps more so than any other breed. The Berkshire derives its name from the county of Berks, in England, where the breed originated—very probably from crossings and improvements made with both the native breeds mentioned in section 442, and also by means of the Chinese and Neapolitan breeds. The Berkshire is of medium size, and, under fair treatment, has the merit of developing at a steady pace from birth to an early maturity. In its meat, the fat and lean are well intermixed. In color, the Berkshire is black, with white "points"; that is, with a white star or stripe on the face, four white feet, and a white "switch" or end of tail. Its face should be broad and well-dished, and rather short and fine; its ears small, thin, soft, and almost erect; its jowl, full; its neck, short and thick; its back, broad and straight; its hams, thick, round, and deep; its tail, fine, small, and set well up; and its legs, short, fine, straight, and strong. The Berkshires are good grazers, and have proved themselves in every way an excellent breed for the purposes of the Canadian farmer.

The Large Breeds.

448. The Middle and Large Yorkshires.—The York-shire pig is bred in several varieties, known as the Small York-shire, the Middle Yorkshire, and the Large Yorkshire. Though differing greatly in size, they have many characteristics in common; and especially is this true of the two larger sizes. The Middle and Large Yorkshires are very popular in England, owing to their ability to produce, in a short time, a fine quality of bacon, in which the lean meat is well developed. They are long and deep in the body, short in the head, very decidedly
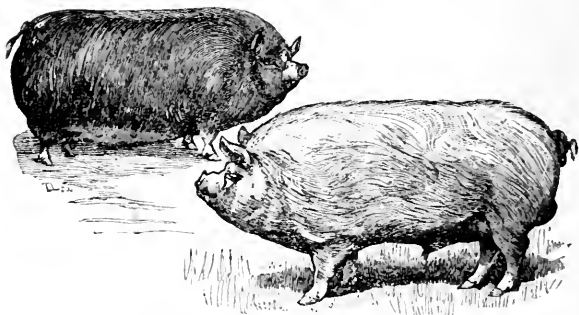
Fig. 60.   Berkshire Sow.   Fig. 70.   Large Yorkshire Boar.
The Berkshire Sow is *Vashti*.   The Yorkshire Boar is *Mammon 5th.*
Both were imported, and are owned by the Ontario Model Farm,
Guelph, Ont.

dish-faced, strong but not coarse in the bone, and covered with a thick coat of silky hair. Their ears are of good size, and point forward without drooping. Their skin is of a pinkish color, with an occasional bluish spot; their hair, however, should always be white. They have been quite largely introduced into Canada, and are fast becoming popular. Though the Large Yorkshires attain to immense sizes (perhaps the greatest of all the breeds of swine), yet they are not coarse animals: their appearance, on the contrary, is rather pleasing: and their bacon, as is charac-teristic of all the Yorkshire varieties, is of the best quality.

449. The Tamworth.—The Tamworth is the most recently

developed of all the British breeds of pigs. It derives its name
from Tamworth, a town on the borders of Staffordshire and
Warwickshire, in England, in which counties the breed is most
numerously found. The Tamworths are descended from an
original race of "sandy-and-blacks," once common in the districts
named. Their first improvement is due to Jonas Webb (see sec-
tion 432), somewhere about 1855, but much greater improvements
have been effected in very recent years. The modern improved
Tamworth is especially noted for the great proportion of *lean*
bacon which it produces; bacon, too, of the choicest quality. The
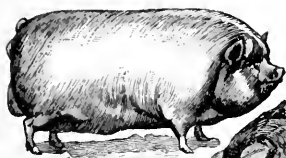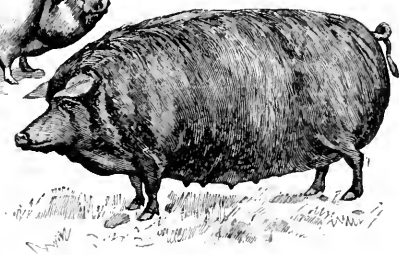

Fig. 71.   American Suffolk Boar.   Fig. 72.   Tamworth Sow.

breed, as improved, are prolific, hardy, quick-growing, and early
to mature. In color, they are red or bright chestnut, inclining
to brown as they grow older; the black spots of the original race
are all bred out. In frame, they are very massive, the body
being long and deep (sometimes 6½ feet in girth, and the same
in length). Their head is small; their ears, medium-sized and
erect; and their snout, inclined to be long. Their hair is silky,
long, and thick, protecting them against both winter cold and
summer heat. In England they have become very popular,
largely so on account of the high market value of their bacon.

450. The Duroc or Jersey Red.—The Duroc or Jersey
Red, often called the Duroc-Jersey, originated in the State of
New Jersey about the middle of this century. They are supposed

to be founded upon the Tamworths of England. The Duroc-Jerseys are a large breed, long and deep in the body, broad rather than rounded in the back, with large ears, lapping over the eyes. In color, they are red, ranging from a glossy cherry, or dark red, or even a brownish color, to a light yellowish red, with occasionally a fleck of black on the under-line and legs.

451. The Chester White.—The Chester Whites are so named from Chester County, Pennsylvania, where the breed originated. They are long and deep in the body, and broad in the back, and have deep, full hams. Their legs are short; their head is short, broad between the eyes, and only slightly dished:
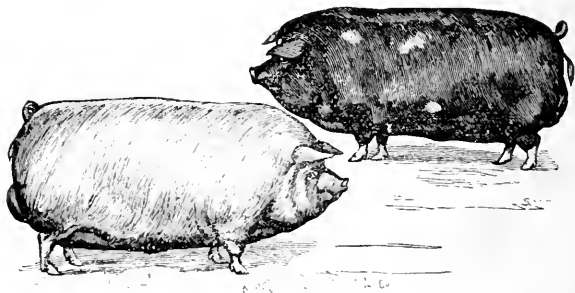

Fig. 73. Chester White Boar.   Fig. 74. Poland China Boar.

and their ears project forward and lap at the point. Their neck is short, thick, and well-arched; and their jowl is large. In color, as their name implies, they are white. Their hair is plentiful, and sometimes a little wavy. The Chester White is, at present, a very popular breed in the United States, and to some extent in Canada, being distinguished for its ability to grow rapidly and mature early. In size, too, it is one of the very largest breeds known.

452. The Poland China.—The Poland Chinas originated in crossings made with several breeds by various stockmen in Warren and Butler counties, Ohio, during the period from 1816 to 1842. Among these original breeds, the white Chinese and the black Berkshire were, perhaps, the most important. **The**

present name of the breed was adopted in 1872. The Poland Chinas resemble the Chester Whites, excepting that their ears droop more, and that their color is black, with spots or sheets of white. The white color is being gradually bred out, so that its markings now are very similar to those of the Berkshire. The Poland China has proved itself one of the most popular of the American breeds; indeed, in the great pork-producing regions of the middle and western States, it is, perhaps, more highly valued than any other breed. It fattens easily and early, and attains to great weights.

CHAPTER XVII.

Dairying.

453. Importance of Dairying.—Dairying has become one of the most important branches of farming in this country. The time for profitable wheat-growing in Ontario, and in all the older provinces of the Dominion, is past. We are no longer in a position to compete with Manitoba, and other new provinces, in producing grain for market. We can, however, raise first-class animals—cattle, sheep, hogs, and horses; and by liberal manuring and proper cultivation of the soil, we can grow good crops of grass, hay, oats, peas, barley, turnips, mangels, Indian corn, rape, etc., to feed these animals. Hence we may profitably devote our attention, not only to the raising of sheep, hogs, horses, and beef cattle, but also to the keeping of cows for the production of milk, cheese, and butter. Ontario farmers have already proved that dairying is a profitable branch of farming in this Province; and much more can be done in the future than has been even thought of in the past.

454. Conditions Favorable to Dairying.—These are (1) plenty of good, pure water at all seasons of the year; (2) soil that will produce abundance of food suitable for cattle: that is,

pasture, hay, coarse grain, and roots or Indian corn; (3) shelter, such as scattered trees or an open grove, to protect cows in hot weather; and (4) buildings, to keep them warm and comfortable in fall, winter, and early spring.

455. Butter or Cheese.—In the neighborhood of cities and large towns, a profitable trade is done in selling milk fresh from the cow; but in most places both dairymen and farmers use the greater part of their milk in making butter or cheese; and which of the two (butter-making or cheese-making) is the more profitable in any particular locality, depends very much upon circumstances. Where dairying is made a specialty, so that the milk of a large number of cows can be got within a short distance from the factory, more money can, as a rule, be made out of cheese than out of butter in this Province; but in localities where mixed farming (grain-growing, stock-raising, and dairying) is carried on, and the skimmed milk is needed for calves and pigs, butter-making is, generally speaking, more satisfactory and profitable than cheese-making.

456. Cows for the Dairy.—Profitable dairy cows use their food so as to make milk rather than flesh; and it is a great mistake to keep, for dairy purposes, any cow which is not a good milker. Some kind of record of the milk given by cows should be kept; and those which fall below the standard in quantity of milk, quality of milk, or the length of the milking period, should be disposed of as soon as possible, and others put in their place. A good dairy cow, with proper food and care, should give milk for at least ten months of the year, and during that time should produce not less than 6,000 lbs. of good milk, $9\frac{1}{2}$ to 10 lbs. of which would make 1 lb. of cheese, and 25 to 28 lbs. of which, when properly set and looked after, would yield cream enough to make a pound of butter.

Of course, great richness of milk, as in the case of that from some Jerseys, makes up for a deficiency in quantity, especially when the cow is kept for making butter; and an unusually large quantity, such as is given by some Holsteins, makes up for a slight deficiency in butter-fat, especially when the milk is used for making cheese.

Some kinds and breeds of cows, as Ayrshires, Holsteins, Jerseys, Guernseys, Canadians, and Shorthorn grades of certain families, seem specially adapted to the production of milk; but two or three things should be borne in mind: (1) that there are poor milkers among cattle of every breed; (2) that, for the dairy, it matters little what the breed or pedigree of a cow may be, so long as she gives a large quantity of good milk, in proportion to the food she consumes; and (3) that, whatever breed is chosen, a herd of good dairy cows can be got and kept only by careful selection, liberal feeding, and good management.

457. Feeding and Care of Cows.—Cows should be well fed at all times; comfortably housed in the cold weather of fall, winter, and spring; and invariably treated with the greatest kindness. Scanty or irregular feeding never pays. A certain amount of food is always necessary to support the animal system, and profit can come only from what is fed over and above that amount. Hence, during the milking period at least, cows should have abundance of wholesome, nourishing food—all that they will eat up clean. Shelter of some kind from the direct rays of the sun in hot weather, and comfortable (not necessarily expensive) stabling in cold weather, are also of much importance, especially the latter; because the exposure of a cow to cold rains in the fall, and to cold winds or frost in winter, or any other season of the year, invariably results in injury to the animal and loss to the owner. Kind and gentle treatment is likewise an important item in the management of cows; for experience has clearly proved that when a cow is made to run, is hunted by a dog, or is kicked, beaten, or otherwise excited by those in charge of her, the invariable result is that she gives less milk, and what she does give is of inferior quality.

Further, in feeding dairy cows for profit, three things are necessary: (1) that they have abundance of succulent food during the milking season, and, if possible, a small allowance of bran; or chopped peas and oats; or ground oats, peas, and barley; or some other mixture of different kinds of meal; (2) that a supply of green-fodder be provided, for use in case pasture become scarce in July, August, or September—say, an acre of oats and vetches,

or peas and oats (sown at different times), and an acre and a half of Indian corn, for 15 cows; (3) that, during winter, the cows be fed and cared for in such a way as to keep them in good health and gaining a little in flesh; because cows that are well fed in winter give milk for a longer period and in larger quantity during the following summer than cows which, from lack of proper and sufficient food, or other causes, have been allowed to run down in flesh and lose the vigor which they had on entering their winter quarters.

458. Water for Cows.—No dairyman can be successful unless he has an abundant supply of water for his cows at all seasons of the year—water which is pure, easily accessible to the cows in summer, and of moderate temperature (not ice-cold) in winter. Cows should have all the water they will drink; and it ought to be *pure;* because impure water is bad for the cow, lessens the value of her milk and its products, and is injurious to the health of those who use the milk, the cheese, or the butter.

459. Salt for Cows.—It is not enough to salt milch cows occasionally, even once or twice a week; nor is it sufficient to give them rock salt to lick. They should have access to ordinary granular salt every day, be allowed to take all they want, and have a little mixed with the cut-feed, meal, etc., which they get in the stable. It has been proved by experiment that cows, when salted only once a week, will generally give from 14 to 17 per cent. less milk than when they have free access to salt every day; and the milk from irregularly salted cows is not so good as that from cows which have a constant supply of salt. It sours sooner, and is otherwise inferior in quality. Hence the importance of placing salt in stables, and under cover in fields, in such a position that milch cows can have access to it at all times, is very evident.

460. Milking.—Each cow should, as far as possible, be milked by the same person, and at the same hour, night and morning. Much milk is lost by frequent changing of milkers, and by irregularity as to time. Before milking, the cow's udder should be well brushed, and then rubbed with a damp cloth. Afterwards, the milker should wash his hands and do the milking

as quickly and thoroughly as possible. Some insist that milking should be done with dry hands, and that every milker should keep a little water by him, and be required to wash his hands regularly after the milking of every two or three cows.

Milk absorbs offensive odors very quickly, and is much injured in quality when kept in bad air for even a short time. Hence milking should not be done in foul-smelling yards or stables, but only where the air is pure.

Further, it is important that milk be strained immediately after it is drawn from the cow, in order that all solid impurities may be at once removed before they dissolve and become incorporated with the milk.

461. Milk Vessels.—All milk and cream vessels should be thoroughly cleansed before they are used—well washed, scalded with boiling water, and exposed to fresh air for several hours. The milking-pails used should be made of tin.

462. Setting Milk.—Milk is very often set in shallow pans, and allowed to stand for some time in a milk-house. It is, however, generally much better to put it into deep cans, say, $8\frac{1}{2}$ inches in diameter by 20 inches deep, and to set these cans in water, as cold as can be got, with the addition of some ice, if possible. Generally speaking, about 18 per cent. more cream can be obtained from milk in deep cans, set in ice-cold water, than from the same milk in shallow pans, set in the ordinary way, without either ice or water; also, by the former method the skimmed milk is kept perfectly sweet, and is thus in a much better condition for the use of calves and pigs.

The water-tank for the milk-cans should be close to a well or spring, protected from the heat of the sun, and away from all smells which might taint the milk. When it is possible, a very good (perhaps the best) way is to construct a sort of open box in the water, near the source of a spring; or in a running stream. If well-water, without ice, is used, it should be changed twice, if possible, for each setting, in order to keep the temperature low enough to separate the cream from the milk—to make it all, or nearly all, rise to the top. A very good plan is to let the fresh cold water from the well enter at the bottom of the tank, and

force the partially warm water out over the top. The nearer the water is kept to 40° or 45° Fahrenheit, the better.

It is important that the milk be set promptly, while it is at or above 90° Fahrenheit. If it is allowed to cool below that temperature, some warm water (150° to 180° Fahrenheit) should be added to the milk, to raise it above 90°, before the cans are set in the cold water. Otherwise, there will not be a complete separation of the cream; and a good deal of it will remain in the skimmed milk.

463. Care of Cream.—Cream should always be removed from milk before the milk becomes sour. All the cream for each churning should be put into one vessel and kept cool, so that it may remain sweet till the time when it is to be soured for churning; and it should be stirred two or three times a day, especially when fresh cream is added. In the hot weather of summer, it should not, as a rule, stand more than three days before churning; and no fresh cream should be put into the vessel within from twenty to twenty-four hours of churning. In order to prepare it for churning, a little ripe cream (that is, cream which has been soured by being kept in a warmer place) should be added to the sweet cream. The cream should then be kept at a temperature of from 60 to 70 degrees (the higher temperature in cold weather), and stirred several times during twenty to twenty-four hours, or till it has reached the right degree of sourness for churning. If no sour cream is added, it will take a longer time, and perhaps a little more warmth, to get it ready for the churn.

A good deal of butter is frequently lost by churning together cream from different vessels, and of different degrees of sourness. This loss arises from the fact that, at the ordinary churning temperature, sour cream gives up its butter in less time, and much more completely, than sweet cream.

464. Churning.—The temperature at which cream should be churned varies from 57 to 60 degrees in summer, and from 62 to 65 in winter. When the particles of butter in the churn are nearly as large as clover seed, some cold water (about one-tenth as much as the milk in the churn, and at a temperature of 50 to 55 degrees) may be added, after which the churning should be

continued till the particles of butter are about half the size of grains of wheat. Then the butter-milk should be drawn off, pure water, at a temperature of 50 to 55 degrees, put in its place, and the churning continued for a short time. This may be repeated once or twice, till the water drawn from the churn is free, or nearly free, from milk. Then the butter in the granular state should be left in the churn for half an hour or twenty minutes to drain, after which it may be taken out and salted.

The temperature for churning sweet cream is 51 to 55 degrees Fahrenheit. When churned by itself within this range of temperature, it gives up nearly all its butter-fat; but the butter from sweet cream is generally considered deficient in flavor.

It is a mistake to continue churning until the butter is gathered into lumps, because in that way a good deal of butter-milk is aken up in the butter, which, if left in the butter, destroys its keeping quality; and the working necessary to remove this butter-milk greatly injures the texture of the butter, very often making it waxy or greasy.

465. Salting and Working Butter.—Pure salt, of medium and uniform fineness, with a velvety touch, should be used--from three-quarters of an ounce to one ounce in every pound of butter. The butter-milk having been washed out in the churn, the butter should not be worked any more than is necessary to mix the salt fairly well with it. It should be kept cool during the working, and set in a cool place for ten or twelve hours to let the salt dissolve, after which it may be worked slightly a second time, and packed away for use.

Some maintain that the best way to salt butter is to put strong brine into the churn and continue the churning for a short time after the butter-milk has been drawn off, and the butter washed by the addition of water, as above. The chief objection to this method is the large amount of brine required in proportion to the quantity of butter salted.

466. Packing of Butter.—When butter is not made into rolls or prints and sold at once, it should be packed in clean,

sweet, and clean-looking tin-lined packages, if possible or convenient; if not, then in crocks, or some other thoroughly clean and neat-looking packages. When put into the package, the butter should be carefully covered with a piece of thin white cotton, which has been washed in warm water and soaked in brine, to remove starch, etc. The outer edges of the cloth should be pressed down, with a table-knife or piece of flat stick, all round between the butter and the sides of the package, after which the butter should be covered to the depth of one-half to three-quarters of an inch with a wet paste of salt, leaving a little brine on the top, to exclude the air. Some fresh brine should be added to the paste from time to time, to fill holes and keep out the air.

467. Milk and Butter Rooms.—Cellars and rooms in which milk or butter is kept should always be cool, as near 45 degrees as possible, well ventilated, and free from foul air, such as might come from decaying vegetables, or other causes.

468. Need of a Thermometer.—A good dairy thermometer can be bought for twenty-five cents, and no handler of milk, or maker of butter or cheese, should ever be without one. Such an instrument is constantly needed to test the temperature of milk at the time of setting, of the water in which the milk-cans are placed, of the cream before churning, the cream in the churn, the water added to wash the butter, etc.

469. Cleanliness.—We cannot emphasize too strongly the importance of cleanliness in everything connected with dairying. The stables in which the cows are fed should be clean; the food and drink of the cows should be pure; the place of milking should be free from foul odors; the milk-pails, the cream-cans, and the hands, nails, and persons of the milkers and butter-makers, should all be scrupulously clean.

470. Cheese-Making.—Cheese-making is a very important branch of dairying, and one which should receive careful attention from every student of dairy husbandry; but as cheese, in this Province, is generally made in factories, and the details of its manufacture are numerous and somewhat complicated, we shall not attempt to describe the process in the brief space allotted to dairying in an elementary text-book on general agriculture.

CHAPTER XVIII.

The Silo and Ensilage.

471. What is Meant by "A Silo" and "Ensilage."—

A *silo* is an air-tight building, or compartment of a building, constructed for the purpose of preserving green fodder for future use. The process by which this preservation is effected is termed *ensilage*. When we preserve green fodder by means of a silo we are said to *ensile* it; and the fodder so preserved is called *silage*. But the word "ensilage" is often used to denote the fodder that is preserved, as well as the process of preservation; so that the word "silage" is of infrequent occurrence, and the word "to ensile" is hardly used at all.

The great value of the silo lies in the fact that by its use green fodders, which otherwise could be fed to animals only in summer-time, can be kept for months in a state as palatable and nutritious as when they were first harvested, and therefore can be fed to cattle and other animals all through the winter and early spring when other green forage is unobtainable. By some indeed, it is said that well prepared ensilage is more digestible and palatable than the green fodder from which it is prepared, though this is denied by others. It is without question, however, that all animals are very fond of it; and that when it is fed to them, properly mixed with other foods, they thrive well.

There are other ways by which green-fodder can be preserved, besides by the silo; as, for example, by means of trenches, or by stacking. But these methods are not so efficient as the silo method, and therefore will not be described here.

472. Crops Used in Ensilage.—

The crop most generally used for ensilage in Canada is *corn*. But other green-crops, as rye, clover, and grasses of various kinds, and peas and various kinds of cereal crops, may also be preserved in the silo. But since corn produces a greater quantity of food to the acre than these other

crops, and since the process of preserving it in the silo has been brought to great perfection, its use as our ensilage crop has become very general if not exclusive, and it is the crop generally understood as being meant when ensilage is spoken of. It is probable, however, that in time clover also will become a popular crop for the silo.

473. Construction of the Silo.—Whether the silo is a distinct building, or a compartment of a building, it should always be placed so as to be easily accessible from the stables where the ensilage is to be used. In barns with basement stables, a portion of the basement with the mow above it, can oftentimes, with great advantage, be converted into a silo; and the construction of such a silo may be easily inferred from what is here said concerning the construction of the silo when a separate building is devoted to the purpose.* For the sake of clearness, we will speak of the several parts of the process of construction separately:

(1) *The site and foundation.* The site chosen for the silo should, if possible, be somewhat elevated, and be well drained to prevent dampness. The foundation should be an eighteen
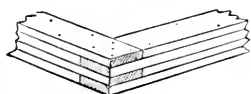

inch stone wall, laid deep enough to be beyond the action of frost, and raised high enough to permit of sufficient grading to divert all surface water from it. The earth excavated for the foundation

Fig. 75. Showing a corner of the sills of a silo.

should be thrown inside so as to raise the floor of the silo to the level of the stone. If this earth is levelled off nicely, and beaten down solidly, no other floor is needed.

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* It should be remarked, however, that when the stone wall of a basement stable is used as one of the sides of a "compartment silo," the side of the wall so used should be lined with smooth boarding, both to facilitate the settling of the stored ensilage, and to prevent the stone of the wall from conducting away the heat generated in the silo. The reasons for this will appear from the subsequent sections. But it may be added that some authorities consider that *plastering* the sides of the foundation walls is preferable to lining them with boarding, as above described.

(2) *The sills.* The sills should be made of three or four layers of planks (2 inches x 10 inches) laid along the top of the foundation in a bed of mortar. They should be cross-lapped at the corners (see Figure 75).

(3) *The studding for the sides and ends.* The studding for the sides and ends should consist of similar planks (2 inches x 10 inches) 16 or 18 feet long, placed from 18 to 24 inches apart. These studs may be fastened to the sill below, either by mortising and "toe-nailing," or simply by spiking. If fastened to the sill by spiking, the topmost plank of the sill should first be firmly spiked to its studs before being spiked to the other planks of the sill. For the corners of the framework, posts ten inches square may be used if convenient, but the studding can be easily disposed so as to make this unnecessary.
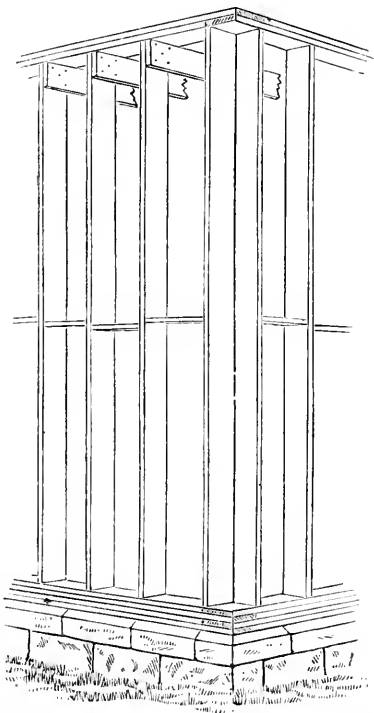

Fig. 76. Showing the foundation, sills, studding, bridging, cross-ties, and plates of a silo.

(4) *The plates.* The plates above the studding may consist of two layers of planks in size and arrangement similar to those of the sills below.

(5) *The cross-ties.* The cross-ties may consist of planks (2 inches x 6 inches), running across from the tops of the studs on one side to the tops of the studs on the opposite side, their ends being immediately under the plates.

(6) *The roof.* The rafters of the roof may be made to spring from the plates above the studs, and meet in a half pitch in the usual way. The covering of the roof should be completely weather proof.

(7) *Bridging the studding.* In order to make the framework of the silo still stronger, so as to prevent all possibility of bulging when the silo is filled with ensilage, the studding should be "bridged." This "bridging" consists in spiking planks between

the studs, placed as nearly as possible in a horizontal line around the four walls of the building. (The arrangement of the studding, the sills, the plates, the cross ties, and the bridging, can all be seen in Figure 76.)
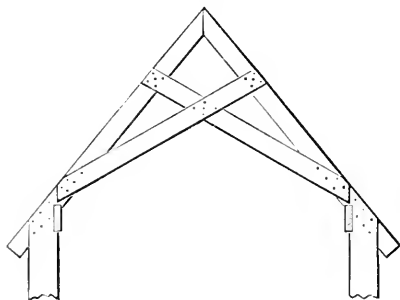
Fig. 77. Showing the construction of the rafters, ribbon, and underbracing of a silo, when cross-ties are not used.

NOTE.—Instead of the plates, cross ties and roof, as described above, a different plan of construction is sometimes followed, which secures as much strength, and permits of greater convenience in filling the silo, and in getting at the stored ensilage when the silo is filled. The studs at the top are held in place by a "ribbon" (1 inch x 8 inches) let into the inside edges of the studs at the top. This ribbon passes all round the four sides of the frame-work. The rafters (2 inches x 6 inches) instead of springing from the plates, spring directly from the studs, against which at the tops they are spiked, and are made to meet at the top in a three-quarter pitch. The "ribbon" above described, is let into the lower edge of each rafter by means of a notch, and thus helps to keep the rafters in place also. When the rafters are in position, underbraces (1 inch x 8 inches) are strung from the bottom of each

rafter to a point in the opposite rafter about two-thirds of the distance from its lower end. These underbraces are also fastened together where they cross one another. The construction of the rafters, ribbon, and underbracing, is shown in Figure 77. When the underbracing is constructed in this way, not only are the sides of the silo greatly strengthened, but a free passage is also secured on the inside of the silo below the roof, which, as was said above, is of great convenience.

(8) *The inner lining.* When the framework is completed as above, the inner lining is put on. The object of the inner lining is to keep in the heat engendered by the chemical action that takes place in the mass of ensilage when first it is stored in the silo; also to keep out all air. Experience has shown that these objects are best secured when the inner lining has a construction as follows: (1) A layer of inch boarding placed horizontally and nailed to the studs all round inside, made to fit closely at the edges, and with close-fitting joints at the corners; (2) a coating of tar-paper, tacked against the boarding; and so laid that its edges lap everywhere by four inches; (3) a second layer of inch boarding, placed horizontally, and made to fit at the edges and corners as closely as possible. In order to allow the easy settling of the fodder when packed against it, this second layer of boarding should be made smooth on its inner side by planing; and to preserve it from decay when exposed to the heat and moisture generated within the silo, it should also receive a coating of coal-tar mixed with resin, applied hot and liberally; or else a coating of crude petroleum, which is easier of application, and by some is preferred for other reasons.

(9) *The outer covering of the silo.* The outer covering of the silo is principally to keep out frost, and this object is best effected by making it as nearly air-tight as possible; for in this way a mass of air is confined between the outer covering of the silo and the inner lining, which, being a good non-conductor, permits very little cold to enter, or heat to escape. Experience has shown that the outer covering may be constructed in very much the same way as the inner lining; but of course the outside boarding, instead of being coated with coal tar or crude petroleum, may be painted with any ordinary paint, or left wholly unpainted, if desired. Some authorities think it practicable to dispense with one layer of boarding, and use only the layer of tar-paper and

the outside boarding; but our winters in Canada are so cold that this method of construction is not recommended.

(10) *The corners of the silo.* It is advisable not to leave the corners of the silo (where the walls meet) perfectly square, but rather to break them by means of boards or planks placed perpendicularly in the corners, and made to fit closely by means
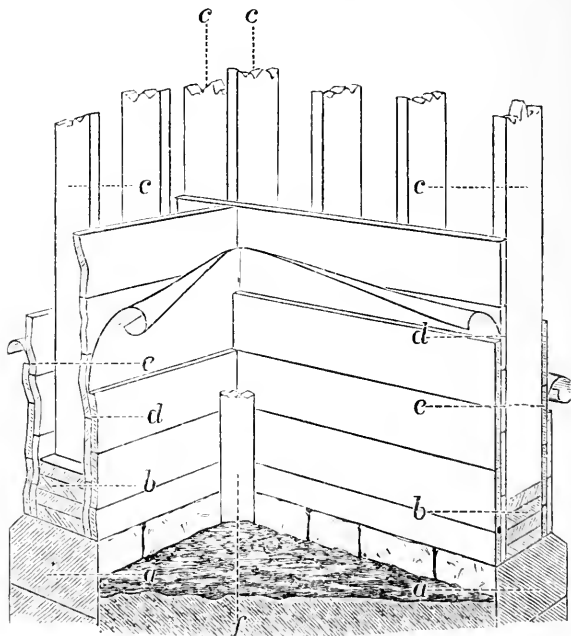

Fig. 78. A section of a corner of a silo, viewed from the inside. (*a*) Foundation ; (*b*) sills ; (*c*) studding ; (*d*) inner lining, consisting of two layers of inch boarding, and one thickness of tar-paper between them ; (*e*) outer covering, similarly constructed ; (*f*) corner-board.

of bevelled edges. The disposition of these corner-boards may be inferred from Figure 78. The spaces behind the boards should be filled with saw-dust, so as to exclude all air as much as possible.

(11) *The door of the silo.* The door of the silo needs

particular description. The place for the door should be the space between two studs in a convenient part of the silo, say, in the middle of one side, or of one end. The door usually extends from the sill almost or even quite to the top of the studding. The door is in reality a *double door*, the outer part corresponding to the outer covering of the silo, and the inner part corresponding to the inner lining. The outer part should be hung on hinges, and may, for convenience' sake, be divided into three or four sections, each swinging on its own hinges, and having its own fastening. The inner part of the door is in reality a movable portion of the inner lining. It may be constructed thus: When the inner lining is completed, saw out the parts of it between the studs of the doorway flush with the studs, and, preserving the pieces, fasten them together in sections, so that they can be put up in their places or taken down at will. Then to the studs of the doorway affix cleats, against which these pieces can be temporarily nailed. When the silo is to be filled, put the pieces comprising the inner door in their proper places, and nail them temporarily to the cleats, taking care to use tar-paper as packing, so as to make all joints perfectly air-tight. When the ensilage is to be used, the silo is entered by the storing-door (see next paragraph), and then the upper section of the inner door can be removed (by withdrawing the nails that fasten it to the cleats) and the ensilage passed out as desired (see section 475). As the ensilage is used, other sections can be removed in the same way.

(12) *The storing-door.* The storing-door is used for filling the silo; it is simply a close-fitting door, hung in an opening in one of the gable ends of the silo. It is by the storing-door also that the silo is entered when it is full. Sometimes the storing-door is placed like a dormer window in the roof of the silo; but this, of course, is a more expensive plan than the one here given.

(13) *Ventilation of the silo.* A good deal of moisture arises from the ensilage during the heating process; and, as far as possible, this should be removed by ventilation; else it would congeal against the roof in cold weather, and drop back again upon the ensilage when mild weather came. Openings in the

gable ends of the silo can easily be made, so as to furnish all the
ventilation required.

(14) *Preparing the silo for use.* When the silo is built, it
should be prepared for use by putting a layer of from six inches
to a foot of straw, either cut or uncut, but dry and clean, upon
the floor of the silo.

474. Filling the Silo.—The operation of filling the silo
comprises (1) the cutting of the corn in the field; (2) drawing it
in; (3) cutting it into short pieces for convenience in handling and
packing; (4) carrying it into the silo; (5) the proper disposition
of it there; and (6) the protection of it from the air and frost
when it is finally deposited there. We shall speak of each of
these parts separately:

(1) *Cutting the corn in the field.* Corn that is intended for
ensilage should be well advanced towards maturity before it is
cut. When the silo was first introduced, the mistake was made
of cutting the corn before it was sufficiently ripened, and the
resulting ensilage was always more or less "sour." Later
experience has shown that the best and "sweetest" ensilage is
made when the corn *has just passed the glazing stage* in what are
called the "flint" varieties of corn, and when it *is well dented*
in what are called the "dent" varieties. Moreover, the corn
cut at this degree of maturity gives a greater yield per acre, and
is, pound for pound, much more nutritious than when it is cut
at an earlier stage. The corn should be cut by means of an
ordinary corn-knife, or common sickle. If it is sufficiently
matured, the cut corn may at once be put, by the person cutting
it, upon the truck used for drawing it in, provided also that it is
sufficiently free from outside moisture. But if it is not suffi
ciently matured, it should be left upon the ground, in little
bundles, to dry and wilt for one or two days; or, if it is wet from
dew or rain, it should, if possible, be left until this moisture is
evaporated. Care, however, should be taken that the corn is
not allowed to become too mature, or to become too dry from
wilting, since two injurious results would then ensue: (1) The
ensilage would not pack closely enough in the silo to exclude the
air, and, on opening the silo, it would generally be found to
be "fire-fanged" and permeated all through with a white mould;

(2) the ensilage would be deficient in that succulent property which is the most valuable feature of good ensilage when used as a winter food for animals.

(2) *Drawing the corn from the field to the silo.* In drawing the corn from the field, long low trucks should be used, for the sake of convenience in loading. Each truck should be long enough and low enough to permit at least a ton of the green corn to be put upon it at once, without the necessity of the teamster climbing up on the load, or of the corn being handled by more than one person. Every farmer will be able to devise trucks for himself; but Figure 79 shows a convenient form of a rack which can be attached to any ordinary farm wagon, the reach being suitably lengthened. The foundation of the rack consists of two planks (2 inches x 8 inches), 16 feet long, the forward ends being placed on the top of the front bolster of the wagon, and the rearward ends being chained or bolted fast to the bottom of the hind axle. The cross-bars, which lie upon the foundation

Fig. 79.   Rack to be used with ordinary farm wagon in drawing in corn. It will be noticed that the top of the rack does not extend wholly back to the rear-end of the foundation; this is to allow room for the hind wheels.

pieces, are planks (2 inches x 4 inches), 7 feet long. The top of the rack is made of common inch boards. In practice, two trucks should be used, so that the corn from one can be cut and deposited in the silo while the other is afield, the horses being changed from one truck to the other at every trip.

(3) *Cutting the corn into short pieces for convenience in handling and packing.* Corn can be preserved in the silo without being cut into short pieces; but several advantages are gained by cutting it, amongst which may be mentioned: (1) The corn when cut is much more easily handled, both in putting it into the silo and afterwards in feeding it; (2) it packs much more closely, and thereby saves a great deal of space in the silo, and also secures a greater exclusion of air, which is a matter of the utmost importance, as will be seen by section 476 (4) and (5);

(3) the cut ensilage is much less likely to be wasted by the animals eating it than ensilage left uncut.   The practice of those most experienced in ensilage is to cut the corn immediately it is brought from the field, removing it, for that purpose, from the truck just as it is needed.   The cutting may be done in an ordinary cutting-box, driven by horse or steam power, provided it be of large enough capacity.   Experience has shown that when the corn is cut into lengths of about two inches each, the pieces are sufficiently fine to pack well and to secure a sufficient exclusion of air in the silo, though some authorities recommend shorter lengths.

(4) *Carrying the cut corn into the silo.*   The corn is usually conveyed into the silo by "carriers," worked by the same power that drives the cutting-box.   The carriers are made to pass direct from the cutting-box, through the storing-door, to a point as nearly as possible above the middle of the silo; and thence the cut corn drops freely downwards, forming a heap.   Sometimes a "shoot" is used, especially if the silo is a large one, by means of which the cut corn can be made to fall in any part of the silo desired.

(5) *Disposition of the cut corn in the silo.*   As the filling proceeds, care should be taken to keep the mass in the silo as level as possible, by frequently shoving the heavier parts, which tend to lie on the middle of the heap, out towards the sides and corners of the silo; also to pack the outer parts firmly down against the walls of the silo by tramping.   The filling may proceed continuously day by day, until the whole of the corn is stored away; or it may proceed at intervals of a day, or even two days, at a time, if necessary.   But if left longer than two days before being finally protected, the ensilage at the depth of two or three inches from the exposed top of the mass usually begins to mould.   In any case, whenever the work of filling has been suspended, the parts along the sides and corners should be carefully tramped down before the work of filling is begun again.

(6) *Protecting the ensilage when the storing is completed.* When the filling is completed, a layer of from one to two feet of cut straw, or even of uncut straw or cornstalks, should be placed upon the top of the cut corn, and this also should be

carefully tramped down, especially at the sides and corners, where indeed it should be tucked in along the edges, the object being to exclude the air from the ensilage as completely as possible. Then the silo should be examined daily for a couple of weeks, and the covering pressed down and kept air-tight, until all settling has ceased. From that time onward, it may be left undisturbed until the ensilage is needed for feeding, whether that be in a month or not for ten months. But the ensilage ought not to be begun to be used within at least four weeks from the time the storing is completed.

475. Removing the Ensilage from the Silo.—When the ensilage stored within the silo is needed for feeding, the silo should be entered through the storing-door, and the covering near the top of the main door-way removed. Then the first piece of the inner door should be taken off by withdrawing its nails from the cleats. The ensilage, then, as desired, may be passed out through the opening thus made into the space between the doorway studs, down which it can be let fall to the bottom, and from there be taken out through the lowermost section of the outer door. Or, it may be at once passed out through the uppermost section of the outer door, if this plan be more desirable. As the ensilage is used, other pieces may be taken off the inner door, as convenience will suggest.

If the silo is not frost-proof above, the ensilage, when uncovered, is liable to become chilled, in which condition it ought not to be fed to cattle. Therefore, to avoid chilling, only as much of the top covering should be removed at any time as is necessary. The chilling may also be further guarded against by filling the roof of the silo, above the under-braces, with straw.

476. Theory of the Silo.—The theory of the silo is not very well understood, nor is as much of it as is understood capable of easy explanation. The following remarks are offered : The object of the silo is to preserve green-fodder, for future use, in a condition as nearly as possible like the condition in which it was when first cut. Perfect preservation, however, is impossible ; for certain changes, which may be described as decompositions and fermentations, are continually taking place from the time of storing until the ensilage is removed for

use. But the endeavor of the farmer should be either to prevent these changes as much as he can, or else to make them conduce, as far as possible, to the palatableness and wholesomeness of the ensilage when it is used as food. In what is called "sweet" ensilage, the changes that take place do certainly conduce somewhat towards the palatableness of the fodder, and therefore the object should always be to produce as sweet a quality of ensilage as possible ; and this is effected by observing the instructions given in the previous sections. We shall place what we have to say of the theory of the silo under several heads, as follows:

(1) *Decomposition sets in, and this is attended by the production of heat.* The material stored away within the silo consists of a mass of plant substance, of which the cells are still alive, and these living cells have the power of sustaining a chemical action which was one of their principal functions when they formed part of the growing plant, namely, to absorb oxygen from the air and to unite it with the carbon and hydrogen of their own substance, and thus produce and set free carbonic acid gas and water-vapor (see sections 7 (1), 7 (3), and 17 (2)). This production of carbonic acid gas and water-vapor is, in reality, a slow process of burning, or combustion, and is accompanied by the production of heat (see also section 300). But, of course, it is also accompanied by the decomposition or wasting away of the plant substance sustaining it. When the plant was growing, the substance thus decomposed was at once replaced by new substance absorbed from the earth and air (see section 22); but in the silo, dissevered from the earth and cut in pieces, the plant substance cannot thus be renewed, and, were the decomposition to go on unchecked, the whole material stored within the silo would soon become destroyed.

(2) *Fermentation also sets in, and it also is attended by the production of heat.* To understand this, it must be remembered that all organic matter, when not sustained by vital activity, is subject to decay, and that this decay takes place in many forms. But these forms may all be described as the rapid growth of low kinds of plant life, feeding upon the decaying organic substance, and having their origin in minute organisms, which exist almost everywhere (as, for example, in the air, floating), and need only

suitable conditions to begin their activity and make their presence noticeable. Souring, rotting, putrefaction, fermentation, mildewing, moulding, are all different forms of decay which organic matter is subject to, and which owe their origin to the dissemination everywhere in the air of their own peculiar germs or spores (which we may understand to be a sort of "seed"), produced in previous decay of like kinds. As long as organic matter is alive, it resists the attacks of these germs or spores, and so does not decay. But when, as described in the preceding paragraph, the plant cells of the forage stored within the silo begin to be decomposed, and to be converted into carbonic acid gas and water-vapor, some of the decaying processes enumerated above also begin, the particular kind or kinds depending largely upon the temperature to which the decomposing substance is raised by the heat evolved in its decomposition, but also upon the degree of maturity reached by the fodder-plants before they were stored in the silo, and, too, upon the amount of moisture present. As a matter of fact, it is generally some sort of *fermentation* that takes place; that is, some low form of plant-life, which we call a "ferment," is produced; the germs necessary to its production being present in the air imprisoned amid the material of the ensilage, and the heat generated in the production of the carbonic acid, described above, being the condition favorable to their development. This fermentation is accompanied by the production of more heat and more carbonic acid, and, of course, by the absorption of more oxygen. But whether this oxygen is obtained from the free oxygen of the air imprisoned within the mass, or from the organic matter of the plant substance upon which the fermentation sustains itself, is not definitely settled. *The balance of authority seems to lie with the first supposition.*

(3) *The heat thus produced tends further to settle the mass and exclude the air.* The heat produced by the decomposition and fermentation above described has the effect of expanding the imprisoned air and driving it partially out of the mass, thereby causing a downward movement of the particles of the mass, owing to their weight, which movement results in their coming

more closely together, and forming a denser and more nearly air-tight packing than before.

(4) *With the exclusion of the air, decomposition ceases.* The mass having now become more tightly packed than ever, the supply of air, and therefore of free oxygen, is necessarily limited, and the production of carbonic acid must finally (almost) cease, and therefore the decomposition of the ensilage must finally (almost) cease also. Of course, decomposition never does absolutely cease, for the mass is never absolutely cut off from communication with the outer air.

(5) *With the exclusion of the air, the fermentation ceases also.* It has been found by experience that when the storing of the ensilage has been properly effected, in the manner previously described, the fermentation, after awhile, to a great extent ceases also. But whether this is due to the fact that all the supply of oxygen available in the air enclosed within the mass is exhausted in the production of carbonic acid and water-vapor, or to the fact that the heat generated by the decomposition and fermentation which take place finally destroys the germs of the ferment, and so renders further fermentation impossible, is not fully determined. *The balance of authority seems to lie with the first supposition.*

477. Practical Remarks, Based on the Theory of the Silo.—The following practical remarks, based on the theory of the silo as set forth in the preceding section, are offered :

(1) *Ensilage is never perfectly preserved fodder.* But although this is true, nevertheless ensilage can be preserved so as to serve, in every way, the useful purposes of the forage from which it is prepared.

(2) *The forage intended for storing should be cut at the right degree of maturity.* When it is cut too early, not only is the plant substance thus obtained less nutritious than when it is cut at a later stage, but there is proportionately a less quantity of it. Moreover, owing to the presence of the watery juices peculiar to immaturity, fermentations (acetic) set in, which render the ensilage sour and unwholesome. On the other hand, when it is cut too late, or left to become too dry by wilting, "fire-fanging" and moulding are almost certain to occur.

(3) *It should also, if possible, be free from extraneous moisture.*

The presence of extraneous moisture (as that from rain or dew) produces an effect similar to the presence of too much watery matter in the plant substance; namely, it conduces towards acetic fermentations, and so renders the ensilage more or less sour and unwholesome.

(4) *The great object to be attained in filling the silo is the exclusion of the air.* When the air is well excluded at first, a high degree of temperature is reached soon after the silo is left to itself; and this high temperature, by expanding the air, causes a further settling of the mass, which results in a greater exclusion of air, and therefore a greater perfection of the preservative process.

(5) *Wherever the air permeates the mass, there is danger of either fermentation or moulding.* Hence, for some time after the silo is filled, while the mass is settling, the covering at the top should be carefully attended to, so that, as far as possible, there shall be no chance of air entering the mass through the covering.

(6) *Since the exclusion of air is so important, it is easily seen why, in filling the silo, the work of making an even distribution of the particles of the mass should be carefully attended to.* Naturally, the heavier particles fall in the middle of the heap, and the lighter ones flutter off to the sides. The object, therefore, should be to make the distribution as even as possible, that the mass may be everywhere of the same density; so that, when it is left to itself, it may settle uniformly.

478. Feeding Ensilage.—As remarked in section 474 (6), when the ensilage has been about four weeks in the silo, it is ready for use; and it may quite properly be used for food from that time until the silo is needed for refilling. The uses to which ensilage may be put as food are varied, being, in fact, very much the same as those of the green-fodder from which it is prepared. Indeed, it may be said to take the place of grass in the long autumn and winter season when grass is unattainable. When fed to dairy cattle, and to the breeding stock of the farm, it stimulates the production of milk; and it is perhaps, when used in this way, that its highest usefulness is attained. Therefore, it forms a most valuable ingredient of the daily ration given to

these animals; but as it is a food which contains a large amount of water, and only a comparatively small portion of nutritive (nitrogenous) constituents, the best results can be obtained from the use of ensilage only when it is fed with some grain food, such as bran, or ground peas and oats; and especially is this true when it is used as a food for beef-producing cattle. It is also a good practice to feed a small quantity of hay (preferably, clover) along with it. Ensilage may also be used as a part of the ration given to young cattle, sheep, and horses.

479. Size of Silo Required for an Ordinary Farm. —A silo 18 feet by 20 feet, and 18 feet high, inside measurement, will hold about 100 tons of well-preserved corn ensilage. This allows the ensilage to settle, so that its depth is about 14 feet. Every farm of 100 acres, that is devoted to general farming, should have a silo upon it of at least this capacity. Twelve tons of corn ensilage may be counted upon with certainty as producible per acre; and two tons of ensilage, *prepared from corn that has been sufficiently matured*, have a feeding value for the production of milk, or for the maintenance of cattle, horses, and sheep, equal to that of one ton of ordinary hay.

480. Importance of the Process of Ensilage. —The importance of converting green-crops into ensilage has incidentally been more or less brought out in the preceding sections, but it may be well here, in conclusion, to summarize its chief advantages as follows: (1) It enables green fodder to be supplied to dairy cattle the whole year round, and thus makes possible the practice of winter dairying, one of the most profitable departments of farm work that the farmer can enter upon.

(2) It enables the farmer to raise a larger quantity of food, suitable both for dairy purposes and for beef, mutton, and wool production, than he could otherwise do, and thereby permits him to stock his farm much more heavily than he could otherwise profitably do, and thus it increases his profits per acre.

(3) It economizes the labor of the farmer, since the preserved ensilage can be more easily got at, and, moreover, be more easily carried to the stock feeding upon it by means of trucks or baskets, than an equivalent amount of other fodder.

(4) It economizes storage room. Especially is this true of

ensilage that is made from forage plants that are cut into pieces before being stored in the silo.

(5) The use of ensilage in winter affects beneficially the health of the animals fed with it.

(6) Ensilage affords a good substitute for roots, both for milk production and for flesh and fat production; and by some authorities it is claimed to be superior to them.

(7) The cultivation of the land required for ensilage crops, when properly done, has a very beneficial effect upon the farm, both in keeping it free from weeds, and in getting it into good condition for subsequent crops.

CHAPTER XIX.

The Cultivation of Forest Trees, for Shade, Ornament, and Protection.

481. Uses of Forests.—The following are among the principal uses of forests:

(1) They are our sources of timber and lumber, and are one of our chief sources of fuel.

(2) They affect the climate of a country favorably (that is, during the heat of summer) by making the days cooler, and the nights warmer. They also retard the evaporation of water from the soil, and hence cause the rainfall to be more evenly divided throughout the year; that is, they cause showers to be more frequent, although they do not increase the amount of the rainfall in the aggregate.

(3) They affect the salubrity of climate, not only by causing a more even temperature and a more even rainfall, but also by absorbing carbonic acid gas and exhaling oxygen. These processes, however, take place only in daylight.

(4) The presence of forests influences the steadiness of the flow of water in streams and rivers. Rain that falls in a forest-clad country does not at once rush over the surface of the ground to form destructive floods, but is more or less arrested by the leaves

of the trees, from which it is at once evaporated. But much of it also slowly percolates through the forest soil, which is generally more porous and absorptive than other soils, to the roots of the trees, whence, in time, it rises to the leaves, to be there evaporated likewise. The humidity of the atmosphere, thus caused by the evaporation from the leaves of the trees of a large portion of one fall of rain, soon results, in turn, in another fall. In this way not only is the total rainfall more evenly distributed throughout the year, but the supply of water for the streams that originate in the forest is made much more continuous and steady.

(5) In cold climates, forests are of immense service as a protection against cold blustering winds, which freeze out winter crops in exposed places, and cause snow to accumulate in drifts on the highways. Moreover, the melting, in springtime, of the snow in forests is generally slow and gradual; hence the presence of forests helps to prevent spring freshets, oftentimes the cause of serious damage.

Summing up, therefore, it may be said that the removal of forests tends to render land infertile, because of (1) the excessive dryness of the soil which the greater rapidity of evaporation caused by the loss of the forests occasions; (2) the greater extremes of temperature which ensue; (3) the increased destructiveness which the winds effect, owing to their greater freedom when they are unobstructed by forests; and (4) the increased destructiveness which falls of rain effect, owing to the fact that, in countries destitute of forest, they are of comparatively infrequent occurrence, and therefore, when they do occur, are usually very heavy, and so cause large quantities of water to rush over the surface of the ground, and thus wash away the best portions of the soil.

It will be seen, then, that in a country which, like our own, has once been well covered with forests, their complete removal may very seriously affect both the climate of the country and the fertility of its soil. Therefore it should be the duty of every one owning land either to preserve some of the original forest of the land, or to supply its place by trees planted in suitable places and specially cultivated.

482. The Purposes for Which Forest Trees are

Cultivated.—The greater part of this Province was once covered with magnificent natural forests; but as these are now almost wholly removed, it becomes necessary for the farmer, if he wishes to make use of forest trees, to cultivate them specially. The purposes for which forest trees are usually cultivated are generally to afford (1) shade; (2) adornment; and (3) protection from winds. They are also occasionally cultivated for the profit to be obtained from the sale of the timber or fuel produced by them.

483. The Two Chief Classes of Forest Trees.—The two chief classes of forest trees in this country are (1) the *deciduous trees*, or those that shed their leaves in autumn; and (2) the *conifers*, or those which bear cones. The latter are verdant throughout the year, and are therefore said to be *evergreen.**

484. Methods of Propagating Forest Trees.—There are three principal methods of propagating forest trees: namely, (1) from the seeds; (2) from parts of living trees, as cuttings, layers, etc.; and (3) from young stock, obtained either from where they have naturally grown in forests or other places, or from nurseries, in which they are grown from seeds or cuttings by special cultivation. The last method is the only one we shall treat of in this chapter.

485. Propagating by Transplanting.—When trees are to be raised from young stock already partially grown, they do better for being transplanted once or twice, according to variety, before being finally planted out. This has the effect of increasing the number of their fibrous roots. The *best age* for final transplanting depends much on the variety of the tree; as, for example, the nut-bearing trees, which have tap-roots, should

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* In some countries, where the climate is milder than ours is, there are evergreen trees which are not conifers; as, for example, the evergreen oak and magnolia of the Southern States, and the holly and box of Southern Europe. Deciduous forest trees are also divided into two classes: namely, (1) *hard-wood trees*, as, for example, the oak, the maple, the elm, the birch, and the beech; and (2) *soft-wood trees*, as the poplar, the willow, the bass-wood, and the horse-chestnut. Hard-wood trees are, as a rule, slower in growth, and more durable, than soft-wood trees.

be transplanted when they are young, and be at once placed in their permanent situations; while other trees, as the oak, the maple, the ash, the elm, which have branching roots, may be transplanted at a more advanced age, and do the better for being transplanted three or four times before being permanently located. In the process of transplanting, care should be taken that the roots be not long exposed to the air, especially in the case of conifers. The *best time* for transplanting is in the spring, just as soon as the ground is dry. This also is especially true of the conifers.

486. Modes of Planting.—These are determined largely by the situation of the place intended to be planted, the nature of the soil, and the object sought for by the planter.

Rocky and broken surfaces cannot be put to a better use than the growing of forest trees; for in this way they may be transformed into objects of beauty, and become, moreover, sources of revenue. In planting such surfaces, no attention can be given to regularity; neither is regularity desirable.

On land capable of being plowed and tilled, some definite order of planting ought to be observed, so that the cultivation of the young trees may be the more easily accomplished. Either one or other of two orders of planting is usually observed, namely, the *square order*, and the *quincunx order*. In the square order, the trees are set in rows, so that each tree is at the corner of a square. In the quincunx order, a similar style is followed, but a tree is also placed at the central point of each square; in this way a gain in number of about 15 per cent. is made, without overcrowding the trees.

In planting a hillside, the trees should be set in rows parallel to the crown of the hill, since this tends to prevent the earth of the hillside from being washed away.

487. Planting Trees for Shade.—In planting trees for shade, care should be taken to put them where they will not interfere with cultivation. The practice of growing "borders" or masses of trees along the fence lines is not to be encouraged, since it interferes with the cultivation on both sides of the fences. For the same reason, on all arable land, trees should be grown but sparingly in groups in the open spaces of the field, and even

when planted singly, the planting should be done but sparingly. In fields with permanent fences, the best places for them are the corners.

488. Trees Most Suitable for Shade.—The trees most suitable for shade are the oak, the elm, the maple, the white ash, and the bass-wood or linden. Of these, the elm is the most hardy. In soils abounding in limestone, or in rich loam, the walnut, butternut, and hickory, grow well, and become most shapely trees.

489. Planting Trees as Adornment to the Landscape.—No adornment of the landscape can excel that of trees planted on the boulevarded sides of private roads and public highways. In preparing land for such use, cultivate it thoroughly for one season, levelling it suitably, and leaving a proper roadway in the middle. Then sow with grass, and plant the trees in single, double, or triple rows, or in any other order that may be desired.

490. Trees Most Suitable for Adornment.—The trees most suitable to plant for adornment are the same as have been mentioned as being suitable for shade trees. To these may be added the horse-chestnut, the paper birch, the mountain ash, the locust, the pine, the cedar, and the Norway spruce.

491. Planting Trees for Protection as Windbreaks.—Windbreaks are of immense importance in a climate such as ours. They may be made to shelter fields, orchards, yards, and buildings, wherever these are exposed to bleak winds, and also to protect highways. They also serve, by retarding direct evaporation from the soil, to make the temperature and moisture of soils more evenly distributed throughout the year. Every farm with a windbreak upon its windward side is much increased in value thereby.

492. Trees Most Suitable for Windbreaks.—Rapid-growing, hardy trees are of course the best, as, for example, the elm, the ash, and the maple. Among evergreens, the Norway spruce is the best; and perhaps it is the best of all, owing to its very rapid growth, its habit of branching low, and its extreme hardiness. Moreover, it bears close planting better than other evergreens, since its branches grow well even when thickly

interlocked with one another. It should have a good, strong, moist soil, but not one that is wet. When several varieties of trees are grown, the Norway spruce should be put on the most exposed side.

493. Suitable Widths for Windbreaks.—A single row of Norway spruces, planted from four to eight feet apart, will soon make an effective windbreak ; but some prefer to make two or three rows out of the same number of trees, since this plan allows more room for development. On the side of a farm that is much exposed, windbreaks may be planted to a depth of several rods. A windbreak of such magnitude assumes the character of a plantation or forest, and may be made a source of revenue. In every case the evergreens should be planted on the side of the windbreak that is most exposed.

494. The Planting and Cultivation of Windbreaks.—The ground intended for the windbreak should, if possible, be well cultivated for the year previous to planting in order that it may be clean and loose. When the time for planting has come, the plough should be used to make light straight furrows in which to place the young trees. If Norway spruces are used, they may be put in when only a few inches high, at which age they may be obtained from the nursery-man at low rates. The ground along the rows should be kept clean and well-stirred until the young trees are several feet in height.

495. Pruning.—The best time for pruning forest trees is in the autumn, for then the wood is ripe and there will be no loss of sap from the wounds made by cutting. Some, however, would recommend the early spring, just before the sap begins to ascend. The pruning consists mainly in removing the lower branches, so that the trunks shall be smooth and shapely. When the trees are planted singly, and are intended for shade, the branches should be allowed to grow on at least two-thirds of the stem. Planting trees thickly at first, and afterwards thinning them from time to time, has the effect of making their stems straight and tall.

FINIS.